

1/5w
AF
2872 \$

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE HONORABLE BOARD OF PATENT APPEALS AND
INTERFERENCES

In re the Application of

Masahiro GOTO

Application No.: 10/565,242

Examiner: A. LAVARIAS

Filed: January 19, 2006

Docket No.: 126735

For: LIGHT-DIFFUSING SHEET

BRIEF ON APPEAL

Appeal from Group
OLIFF & BERRIDGE, PLC
P.O. Box 320850
Alexandria, Virginia 22320-4850
Telephone: (703) 836-6400
Fax: (703) 836-2787
E-mail: email@oliff.com
Attorneys for Appellants

01/06/2009 SHOHAMME 00000073 10565242

01 FC:1402

540.00 0P

I. REAL PARTY INTEREST

The real party in interest for this appeal and the present application is Dai Nippon Printing Co., Ltd., by way of an Assignment recorded in the U.S. Patent and Trademark Office at Reel 017489, Frame 0722.

II. STATEMENT OF RELATED CASES

There are no prior or pending appeals, interferences or judicial proceedings, known to any inventor, any attorney or agent who prepared or prosecuted this application or any other person who was substantively involved in the preparation or prosecution of this application, that may be related to, or that will directly affect or be directly affected by or have a bearing upon, the Board's decision in the pending appeal.

III. JURISDICTIONAL STATEMENT

The Board has jurisdiction under 35 U.S.C. §134(a). The Examiner mailed a Final Rejection on July 1, 2008, setting a three-month shortened statutory period for response. The time for responding to the Final Rejection expired on October 1, 2008. Rule 134. A Notice of Appeal and a Petition for Extension of Time requesting a one-month extension of time under Rule 136(a) were filed on November 3, 2008. The time for filing an Appeal Brief expires the later of two months from the filing of the Notice of Appeal, or one month from the mailing date of the Notice of Panel Decision if a Pre-Appeal Brief Request for Review is sought. Bd.R. 41.37(c) and Official Gazette Notice, July 12, 2005.

No Pre-Appeal Request for Review was sought. The extendible period for filing the Appeal Brief therefore expires January 3, 2009. This appeal brief is being timely filed on January 3, 2009.

IV. TABLE OF CONTENTS

	<u>Page</u>
I. Real Party Interest.....	2
II. Statement of Related Cases	3
III. Jurisdictional Statement.....	4
IV. Table of Contents.....	5
V. Table of Authorities.....	6
VI. Status of Amendments.....	7
VII. Grounds of Rejection to be Reviewed.....	8
VIII. Statement of Facts.....	9
IX. Argument	14
A. Claims 1 Would Not Have Been Obvious Over Moshrefzadeh in View of Arai.....	14
B. The Counter-Argument of the September 26 Advisory Action Is Irrelevant to the Issue of Whether it Would be Obvious to Combine Moshrefzadeh and Arai.....	17
C. Further Arguments Supporting that Those Of Ordinary Skill in the Art Would Not Believe Arai Could Have Been Combined With Moshrefzadeh to Disclose Claim 1.....	18
D. Claim 2-8 Are In Condition For Allowance Based On Their Dependence From Claim 1	20
X. APPENDIX A - Claims Section.....	22
XI. APPENDIX B - Claim Support and Drawing	24
XII. APPENDIX C - Means or Step Plus Function	25
XIII. APPENDIX D - Evidence Section	26
XIV. APPENDIX E - RELATED CASES APPENDIX	146

V. TABLE OF AUTHORITIES

<u>Cases</u>	<u>Page</u>
<i>In re Gordon</i> , 733 F.2d 900, 902 (Fed. Cir. 1984).	16
 <u>Statutes</u>	
35 U.S.C. §103(a)	8, 9, 14
 <u>Other Authorities</u>	
MPEP §2143.01(V)	16, 17
MPEP §2145(X)(A)	18
MPEP §2143(E)	19
Van Nostrand's Scientific Encyclopedia, 8 th Edition 1995	12, 13

VI. STATUS OF AMENDMENTS

No Amendment After Final Rejection has been filed.

VII. GROUND OF REJECTION TO BE REVIEWED

The following grounds of rejection are presented for review:

- 1) Claims 1-8 are rejected as having been obvious under 35 U.S.C. §103(a) over WO 01/04701 to Moshrefzadeh et al. in view of U.S. Patent No. 6,049,649 to Arai.

VIII. STATEMENT OF FACTS

1. In the rejection of claim 1 under 35 U.S.C. §103(a) the Examiner cites Moshrefzadeh et al. ("Moshrefzadeh") (Figures 5, 7-9; page 14, line 28 - page 15, line 31).
2. Moshrefzadeh describes a "optically dispersing film" (Abstract, Figures 5, 7-9, elements 500).
3. The Examiner asserted the dispersing film 500 was equivalent to the recited light diffusing sheet. (July 1, 2008 Office Action, Item 7).
4. The Examiner asserted Moshrefzadeh describes the recited sheet body and the recited plurality of wedge-shaped parts (Figure 5A elements 502 and 504).
5. The Examiner stated Moshrefzadeh does not disclose that the end of the wedge-shaped parts is a flat surface parallel to the entrance surface. (July 1, 2008 Office Action, Item 7).
6. In the rejection of claim 1 under 35 U.S.C. §103(a) the Examiner cites Arai (Figures 9 and 10).
7. The Examiner asserted "Arai teaches a conventional light modifier sheet for diffusing light." (July 1, 2008 Office Action, Item 7).
8. Applicant disagrees with Fact 7.
9. Arai describes a "propagation direction characteristics modifier." (Figures 9 and 10, element 14, col. 9, line 59 to col. 12, line 45).

10. Arai describes that the propagation direction characteristics modifier has "projection elements" that have "flat regions." (Figure 10, elements 14c, 14g).
11. The Examiner asserted the flat regions 14g of the projection elements 14c describe the recited flat surface at the end of the wedge-shaped parts. (July 1, 2008 Office Action, Item 7).
12. The Examiner asserted it would have been obvious to one of ordinary skill in the art to use the wedges with flat surfaces, as described in Arai, in the light diffusing sheet of Moshrefzadeh "for the purpose of allowing light to be transmitted into the wedge-shaped parts without undue light scattering or back reflection." (July 1, 2008 Office Action, Item 7).
13. The Examiner concluded that it would be obvious to combine the described features of Moshrefzadeh and Arai.
14. Applicant disagrees with Facts 11 and 12.
15. The Examiner did not provide an indication of the skill level of the hypothetical person of ordinary skill in the art.
16. The Examiner did not provide any citation to Moshrefzadeh indicating that undue light scattering or back reflection was a problem to be solved.
17. The purpose of the device of Arai is to collimate light. (Abstract).

18. Arai states "when light is obliquely incident on the flat regions 14g, a degree of parallelization of the [light] in the propagation direction is improved." (Arai, col. 11, lines 39-43).
19. The purpose of the device of Moshrefzadeh is to diffuse light. (Abstract, page 2, line 3, page 3, line 18).
20. Moshrefzadeh states "reflective surfaces are disposed at one or more angles so as to reflect light in a number of different directions." (Abstract).
21. The purpose of claimed invention is to diffuse light. (Claim 1).
22. Applicant argued in the September 16, 2008 Request for Reconsideration After Final (RFRAF) that it would not be obvious to combine Moshrefzadeh and Arai.
23. The September 16 RFRAF argued it would not be obvious to combine a feature from a light collimating device, such as Arai, into a light diffusing device, such as Moshrefzadeh.
24. The Examiner responded to the September 16 RFRAF with an Advisory Action on September 26.
25. The Examiner asserted that 'the recitation "light-diffusing sheet" has not been given patentable weight.' (September 26 Advisory Action).
26. The Advisory Action did not dispute that Arai discloses a light collimating device. (September 26 Advisory Action).

27. The Advisory Action did not dispute that Moshrefzadeh discloses a light diffusing device. (September 26 Advisory Action).
28. Claim 1 recites that the wedges are formed of a resin having a refractive index lower than the material of the sheet body. (Claim 1).
29. The relative values of refractive indexes between parts in an optical device determines how light traveling through one medium will be reflected or bent when it impinges a second medium. (Van Nostrand's Scientific Encyclopedia, 8th Edition 1995, page 2661)
30. Moshrefzadeh discloses triangular structures embedded in a layer. (Fig. 5A, elements 504 and 506, page 14, lines 28-31).
31. The Examiner states the triangular structures 504 describe the recited wedge-shaped parts of claim 1. (July 1, 2008 Office Action, Item 7).
32. The Examiner states the layer 506 describe the recited sheet body of claim 1. (July 1, 2008 Office Action, Item 7).
33. Moshrefzadeh discloses that the layer 506 has a higher refractive index than the triangular structures. (Page 14, lines 28-31).
34. Arai discloses the projection elements 14c are embedded in air (Fig. 10, element AR)
35. Arai discloses the projection elements have a refractive index (n) of 1.492 (Fig. 10).

36. Air has a refraction index of 1. (Van Nostrand's Scientific Encyclopedia, 8th Edition 1995, page 2661)

IX. ARGUMENT

Claims 1-8 are rejected as having been obvious under 35 U.S.C. §103(a) over WO 01/04701 to Moshrefzadeh et al. ("Moshrefzadeh") in view of U.S. Patent No. 6,049,649 to Arai. Applicant respectfully asserts that one of ordinary skill in the art would not have thought it obvious to try and combine the applied references.

A. Claims 1 Would Not Have Been Obvious Over Moshrefzadeh in View of Arai

The July 1 Final Rejection asserts that Moshrefzadeh discloses all of the elements of independent claim 1, other than the recited feature that the end of the wedge-shaped parts is a flat surface parallel to the entrance surface. See Facts 1-5. The July 1 Final Rejection acknowledged that Moshrefzadeh did not disclose this feature. See Fact 5. Rather the July 1 Final Rejection asserted that Arai disclosed this feature. See Facts 7 and 9-12. However, it one of ordinary skill in the art would not have thought it obvious to try and combine the features of Moshrefzadeh and Arai.

Applicant responded to the rejection of the July 1 Final Rejection in the September 16 Request for Reconsideration After Final Rejection ("RFRAF"). See Facts 22 and 23. The September 16 RFRAF argued that Arai discloses a light modifier sheet for collimating outgoing light. See Fact 17. By contrast, the purpose of the wedge shapes in both the instant claims and Moshrefzadeh is to diffuse light. See Facts 17 and 18. Thus, those of ordinary skill in the art

would believe that features designed to collimate light would not be effective to instead diffuse light.

More specifically, Arai discloses a device designed to collimate light. See Facts 17 and 18. In other words, Arai discloses a device designed to output light beams having a uniform, parallel, direction. Arai discloses that "when light is obliquely incident on the flat regions 14g, a degree of parallelization of the [light] in the propagation direction is improved." See Fact 18. The flat region 14g is the feature in Arai that allegedly discloses the recited flat end surfaces of the wedge shapes in independent claim 1. See Fact 11. In other words, Arai discloses that the flat surfaces 14 improve the ability of the device to collimate light.

By contrast, Moshrefzadeh relates to an entirely different type of device. Moshrefzadeh discloses a light diffusing device. See Facts 19 and 20. Moshrefzadeh's abstract summarizes the intended purpose stating that "reflective surfaces are disposed at one or more angles so as to reflect light in a number of different directions." See Fact 20. As can be seen, light diffusing devices are designed to achieve the opposite effect of light collimating devices.

The July 1 Final Rejection asserted that it would be obvious to combine the flat surface of Arai in the light diffusing sheet of Moshrefzadeh "for the purpose of allowing light to be transmitted into the wedge-shaped parts without

undue light scattering or back reflection." See Fact 12. However, as explained above the purpose of Moshrefzadeh's device is to scatter light.

It is well established that it is not obvious to add a feature to a device that would impede its intended use. MPEP §2143.01(V) *citing In re Gordon*, 733 F.2d 900, 902 (Fed. Cir. 1984). As noted above, the purpose of Moshrefzadeh's device is to scatter light. See Fact 20. Thus, those of ordinary skill would not have wanted to insert a feature into Moshrefzadeh that would reduce light scattering. To the contrary, those of ordinary skill in the art would have likely believed that adding a feature from a light collimating device, that is explicitly identified as improving the collimating effect, would impede the function of a light diffusing device.

Furthermore, it is well understood that the scattering properties of a diffusing sheet are based on the angles and placement of the various surfaces that the incident light will contact. See Fact 20. The types of surfaces used, and the placement of these surfaces is carefully chosen based on the desired scattering or collimating effect. See Fact 20. Thus, those of ordinary skill in the art would not believe that a flat surface, defined by Arai as improving the collimating effect on light would be of use in a diffusing sheet. Thus, it would not have been obvious, to one of ordinary skill in the art, to try and combine Arai and Moshrefzadeh.

B. The Counter-Argument of the September 26 Advisory Action Is Irrelevant to the Issue of Whether it Would be Obvious to Combine Moshrefzadeh and Arai

The September 26 Advisory Action responded to the above argument by asserting that 'the recitation "light-diffusing sheet" has not been given patentable weight.' See Fact 25. In other words, the Advisory Action asserted that because this term is in the preamble, and merely recites an intended use, that it does not further limit the claims. See Fact 25. Applicant respectfully asserts that this counter-argument is irrelevant.

The issue at hand is not whether the ability to diffuse light is a limitation on the claims. The issue is whether one of ordinary skill would have believed a feature from a light collimating device, such as Arai, would have any beneficial use in a light diffusing device, such as Moshrefzadeh. As mentioned above, it is well established that it is not obvious to add a feature to a device that would impede its intended use. MPEP §2143.01(V). It is undisputed that Moshrefzadeh discloses a light diffusing device. See Fact 27. Therefore, as explained above, combining the features of Arai into Moshrefzadeh would have rendered Moshrefzadeh unsuitable for its intended purpose.

Thus, it is irrelevant whether the claims recite diffusing light in the preamble or in the body of the texts. The relevant issue is that Moshrefzadeh discloses a light diffusing device. The Office Action fails to consider the references as a whole and relies on impermissible hindsight using knowledge gleaned only from Applicant's disclosure. See MPEP §2145(X)(A). As such, it

would not have been obvious, to those of ordinary skill in the art, to combine Moshrefzadeh and Arai.

C. Further Arguments Supporting that Those Of Ordinary Skill in the Art Would Not Believe Arai Could Have Been Combined With Moshrefzadeh to Disclose Claim 1

As further evidence that those of ordinary skill in the art would not have believed the features of Arai could successfully be integrated into the device of Moshrefzadeh, consider that Arai does not disclose that the wedge shaped parts have a lower refractive index than the material of a sheet body. See Fact 34.

Claim 1 recites that the wedges are formed of a resin having a refractive index lower than the material of the sheet body. See Fact 28. As is well known in the optical arts, the relative values of refractive indexes between parts in an optical device determines how light traveling through one medium will be reflected or bent when it impinges a second medium. See Fact 29.

Moshrefzadeh discloses triangular structures 504 (the alleged wedges) embedded in a layer 506 (the alleged sheet body). See Facts 30-32.

Moshrefzadeh further discloses that the layer has a higher refractive index than the triangular structures. See Fact 33.

By contrast, Arai appears to disclose that projection elements 14c (the alleged wedges) are surrounded by air. See Fact 34. Arai further discloses that the projection elements 14c have an index of refraction of 1.492. See Fact 35. Thus, because air has an index of refraction of 1, Arai discloses that the alleged

wedges have a higher index of refraction than the material surrounded them.

See Fact 36.

Therefore, one of ordinary skill in the art would realize that light impinging on the projection elements 14c of Arai will bend differently than light impinging on the triangles of Moshrefzadeh. Thus, those of ordinary skill in the art could not have easily predicted what, if any, advantageous effects might be obtained by combining the flat surfaced projection elements 14c in the device of Moshrefzadeh.

The new MPEP examination guidelines state that for a combination to be obvious to try the prior art must demonstrate that (1) there was a recognized problem or need in the art; (2) that there were a finite number of potential solutions to the recognized problem and (3) that one of ordinary skill in the art could have pursued those potential solutions "with a reasonable expectation of success." See MPEP §2143(E) (emphasis added).

Those of ordinary skill in the art could not have believed there would be a reasonable expectation of success in combining Moshrefzadeh and Arai. Specifically, those of ordinary skill in the art would have believed that the optical properties and stated intentions of Moshrefzadeh and Arai were so different, as to defeat any expectation of success when combined. Specifically, light impinging on the flat surface of Arai would bend in one way, because it was encountering a structure having a higher index of refraction. By contrast,

light hitting the same flat surface in Moshrefzadeh would bend differently because it would be impinging on a material having a lower index of refraction.

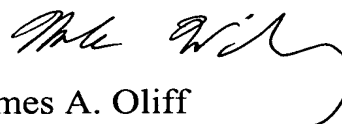
Therefore, based on the reasons above it would not have been obvious to combine the flat wedge feature of Arai in the device of Moshrefzadeh.

D. Claim 2-8 Are In Condition For Allowance Based On Their Dependence From Claim 1

Claims 2-8 depend from claim 1. As discussed above, the rejection of claim 1 lacks merit. Thus, claims 2-8 are in condition for allowance based on their dependence on claim 1.

For all of the reasons discussed above, it is respectfully submitted that the rejections are in error and that claims 1-8 are in condition for allowance. For all of the above reasons, Appellants respectfully request this Honorable Board to reverse the rejections of claims 1-8.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "James A. Oliff", with a stylized flourish extending from the end.

James A. Oliff
Registration No. 27,075

Moshe K. Wilensky
Registration No. 56,263

JAO:MKW/jfb

OLIFF & BERRIDGE, PLC
P.O. Box 320850
Alexandria, Virginia 22320-4850
Telephone: (703) 836-6400
Fax: (703) 836-2787
E-mail: email@oliff.com

Filed: January 5, 2009

X. APPENDIX A - CLAIMS SECTION

1. (Rejected) A light-diffusing sheet having a flat entrance surface and an exit surface parallel to the flat entrance surface, said light-diffusing sheet comprising:

 a sheet body; and

 a plurality of wedge-shaped parts, each being embedded on the side of the exit surface of the sheet body, having a section of a shape substantially resembling a wedge, expanding toward the exit surface, and being formed of a resin having a refractive index lower than that of a material of the sheet body;

 wherein each of the side surfaces of each of the wedge-shaped parts is formed of inclined surfaces constituting a polygonal surface, angles formed by the inclined surfaces of each side surface and the perpendicular to the entrance surface gradually become greater toward the exit surface; and

 an end of each of the wedge-shaped parts on the side of the entrance surface is a flat surface parallel to the entrance surface.

2. (Rejected) The light-diffusing sheet according to claim 1, wherein the angle formed by the inclined surface, nearest to the exit surface, of the side surface of the wedge-shaped part and the perpendicular to the entrance surface is not smaller than twice the angle formed by the inclined surface, nearest to the entrance surface, of the side surface of the wedge-shaped part and the perpendicular to the entrance surface.

3. (Rejected) The light-diffusing sheet according to claim 1, wherein each of the wedge-shaped parts of the light-diffusing sheet is adjusted such that the ratio of light rays reflected in total reflection by the exit surface to all of the light rays incident on the entrance surface at incident angles in the range of 0° to 30° is in the range of 0.1% to 3%.

4. (Rejected) The light-diffusing sheet according to claim 1, wherein the ratio of the refractive index of the wedge-shaped parts to that of the sheet body is in the range of 0.90 to 0.97.

5. (Rejected) The light-diffusing sheet according to claim 1, wherein each of the wedge-shaped parts of the light-diffusing sheet is adjusted such that the ratio of light rays reflected in total reflection at least twice on the side surfaces of the wedge-shaped parts to all of the light rays perpendicularly incident on the entrance surface is 1% or above.

6. (Rejected) The light-diffusing sheet according to claim 1 further comprising an auxiliary diffusing layer formed on the side of the exit surface of the sheet body.

7. (Rejected) The light-diffusing sheet according to claim 1, wherein the wedge-shaped parts are arranged at a fixed pitch P , and the flat end surfaces of the wedge-shaped parts have a width W in the range of $0.1P$ to $0.2P$.

8. (Rejected) The light-diffusing sheet according to claim 1, wherein light-absorbing particles are dispersed in the wedge-shaped parts.

XI. APPENDIX B - CLAIM SUPPORT AND DRAWING
ANALYSIS SECTION

1. A light-diffusing sheet {**abstract; Figs. 1 and 8, element 10**} having a flat entrance surface {**Fig. 1, element 10a; paragraph [0030]**} and an exit surface {**Fig. 1, element 10b; paragraph [0030]**} parallel to the flat entrance surface, said light-diffusing sheet comprising:
 - a sheet body {**Fig. 1, element 11; paragraph [0033]**}; and
 - a plurality of wedge-shaped parts {**Fig. 1, element 14; paragraph [0036]**}, each being embedded on the side of the exit surface of the sheet body, having a section of a shape substantially resembling a wedge, expanding toward the exit surface {**Fig. 1**}, and being formed of a resin {**paragraph [0034]**} having a refractive index lower than that of a material of the sheet body {**paragraph [0034]**};
 - wherein each of the side surfaces {**Fig. 1, element 15; paragraph [0036]**} of each of the wedge-shaped parts is formed of inclined surfaces {**Fig. 1, elements 15a, 15b, 15c; paragraph [0037]**} constituting a polygonal surface {**paragraph [0037]**}, angles formed by the inclined surfaces of each side surface and the perpendicular to the entrance surface gradually become greater toward the exit surface {**paragraph [0037]**}; and
 - an end of each of the wedge-shaped parts on the side of the entrance surface is a flat surface parallel to the entrance surface {**Fig. 1**}.

XII. APPENDIX C - MEANS OR STEP PLUS FUNCTION
ANALYSIS SECTION

NON-APPLICABLE.

XIII. APPENDIX D - EVIDENCE SECTION

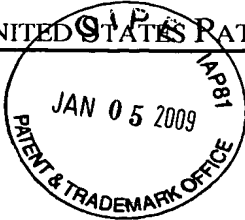
A copy of each of the following items of evidence relied on by the Appellant and the Examiner in this appeal is attached:

Table of Contents

	<u>Page</u>
July 1, 2008 Office Action.....	27
September 26, 2008 Advisory Action.....	37
WO 01/04701 to Moshrefzadeh.....	40
U.S. Patent No. 6,049,649 to Arai	103
September 16, 2008 Request for Reconsideration.....	140
Van Nostrand's Scientific Encyclopedia, 8 th Ed. (Cover Page & page 2661)	144



UNITED STATES PATENT AND TRADEMARK OFFICE

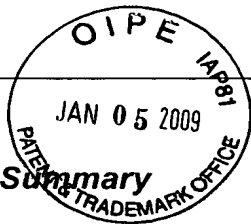


UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/565,242	01/19/2006	Masahiro Goto	126735	9153
25944 7590 07/01/2008 OLIFF & BERRIDGE, PLC P.O. BOX 320850 ALEXANDRIA, VA 22320-4850				
			EXAMINER LAVARIAS, ARNEL C	
			ART UNIT 2872	PAPER NUMBER
			MAIL DATE 07/01/2008	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.



Office Action Summary

Application No.

10/565,242

Applicant(s)

GOTO, MASAHIRO

Examiner

Amel C. Lavarias

Art Unit

2872

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 16 April 2008.
- 2a) ☒ This action is **FINAL**. 2b) ☐ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-8 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 1-8 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892) | 4) <input type="checkbox"/> Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____ |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | 5) <input type="checkbox"/> Notice of Informal Patent Application |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date _____ | 6) <input type="checkbox"/> Other: _____ |

DETAILED ACTION

Response to Amendment

1. The amendments to the abstract and specification of the disclosure in the submission dated 4/16/08 are acknowledged and accepted. In view of these amendments, the objections to the specification in Sections 5 and 7 of the Office Action dated 1/30/08 are respectfully withdrawn.
2. The amendments to Claim 1 in the submission dated 4/16/08 are acknowledged and accepted.

Response to Arguments

3. The Applicant's arguments filed 4/16/08 have been fully considered but they are not persuasive.
4. The Applicant argues that, with respect to Claim 1, as well as Claims 2-8 which depend on Claim 1, the combined teachings of Moshrefzadeh et al. and Arai fail to teach or reasonably suggest an end of each of the wedge-shaped parts on the side of the entrance surface being a flat surface parallel to the entrance surface. The Examiner respectfully disagrees. It is noted that the test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference; nor is it that the claimed invention must be expressly suggested in any one or all of the references. Rather, the test is what the combined teachings of the references would have suggested to those of ordinary skill in the art. See *In re Keller*, 642 F.2d 413,

208 USPQ 871 (CCPA 1981). In the instant case, Arai is being cited to evidence the use of a flattened end, as opposed to a pointed end, of the wedge-shaped parts at a side of the entrance surface for allowing light to be transmitted into the wedge-shaped parts without unwanted light scattering. In addition, the Examiner disagrees with Applicant's argument that both Moshrefzadeh et al. and Arai achieve their goal in two distinctly different manners, since both reflect and transmit light via Snell's law, which is dependent on the refractive indices of the media that the light traverses. The use of a particular material (which thus sets the refractive indices) establishes the reflection and transmission characteristics of the wedge-shaped parts.

5. Claims 1-8 are again rejected as follows.

Claim Rejections - 35 USC § 103

6. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

7. Claims 1, 4, 6-8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Moshrefzadeh et al. (WO 01/04701 A1), of record, in view of Arai (U.S. Patent No. 6049649), of record.

Moshrefzadeh et al. discloses a light-diffusing sheet (See for example Figures 5, 7-9) having a flat entrance surface (See for example upper surface of 506 near 500 in Figures 5A-B) and an exit surface (See for example bottom surface of 502 in Figures 5A-B)

parallel to the flat entrance surface, said light-diffusing sheet comprising a sheet body (See for example 506 in Figures 5A-B); and a plurality of wedge-shaped parts (See for example 504 in Figures 5A-B), each being embedded on the side of the exit surface of the sheet body, having a section of a shape substantially resembling a wedge, expanding toward the exit surface, and being formed of a resin having a refractive index lower than that of a material of the sheet body (See for example Page 14, line 28-Page 16, line 19); wherein each of the side surfaces of each of the wedge-shaped parts is formed of inclined surfaces constituting a polygonal surface (See specifically Figures 8A-B), angles formed by the inclined surfaces of each side surface and the perpendicular to the entrance surface gradually become greater toward the exit surface. Moshrefzadeh et al. additionally discloses the ratio of the refractive index of the wedge-shaped parts to that of the sheet body being in the range of 0.90 to 0.97 (See for example Page 15, line 23-Page 16, line 7; wherein the ratio is 0.95); an auxiliary diffusing layer (See for example 522 in Figure 5B; Page 14, line 28-Page 15, line 22) formed on the side of the exit surface of the sheet body; the wedge-shaped parts are arranged at a fixed pitch P and the flat end surfaces of the wedge-shaped parts have a width W in the range of $0.1P$ to $0.2P$ (See for example Page 15, lines 23-31, wherein the width W is approximately $0.20P$); and light-absorbing particles are dispersed in the wedge-shaped parts (See Page 14, line 28-Page 15, line 31). Moshrefzadeh et al. lacks an end of each of the wedge-shaped parts on the side of the entrance surface being a flat surface parallel to the entrance surface. However, Arai teaches a conventional light modifier sheet for diffusing light (See for example Figures 9-10), wherein the light modifier sheet (See for example 14 in Figures 9-10) includes a

plurality of wedge-shaped parts (See for example 14c in Figure 10) in the form of ridges. Further, these ridges are oriented such that the narrow portions are located near the light incident side of the light modifier sheet. Also, these narrow portions include a flat surface parallel to the entrance surface (See 14g in Figure 10). Thus, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have the end of each of the wedge-shaped parts on the side of the entrance surface be flat surface parallel to the entrance surface, as taught by Arai, in the light-diffusing sheet of Moshrefzadeh et al., for the purpose of allowing light to be transmitted into the wedge-shaped parts without undue light scattering or back-reflection.

8. Claim 2 is rejected under 35 U.S.C. 103(a) as being unpatentable over Moshrefzadeh et al. in view of Arai.

Moshrefzadeh et al. in view of Arai discloses the invention as set forth above in Claim 1. Moshrefzadeh et al. in view of Arai further discloses the angle formed by the inclined surface, nearest to the exit surface, of the side surface of the wedge-shaped part and the perpendicular to the entrance surface being greater than the angle formed by the inclined surface, nearest to the entrance surface, of the side surface of the wedge-shaped part and the perpendicular to the entrance surface (See Figures 8A-B; Page 18, line 20-Page 20, line 12). Moshrefzadeh et al. in view of Arai does not specifically disclose the angle near the exit surface being not smaller than twice the angle near the entrance surface.

However, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have the angle near the exit surface be not smaller than twice the angle near the entrance surface, since it has been held that where the general

conditions of a claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art. One would have been motivated to have the angle near the exit surface be not smaller than twice the angle near the entrance surface, for the purpose of providing additional diffusive focusing of the incident light, which would allow for increased contrast without reducing the overall transmission or viewing angle of the light-diffusing sheet. *In re Aller*, 220 F.2d 454, 456, 105 USPQ 233, 235.

9. Claim 3 is rejected under 35 U.S.C. 103(a) as being unpatentable over Moshrefzadeh et al. in view of Arai.

Moshrefzadeh et al. in view of Arai discloses the invention as set forth above in Claim 1. Moshrefzadeh et al. in view of Arai further discloses that the exit angle of the incident light may be adjusted via the number and angles of the facets on the sides of the wedge-shaped parts (See for example Figures 8A-B; Page 19, line 13-Page 20, line 12).

Moshrefzadeh et al. in view of Arai does not explicitly disclose the ratio of light rays reflected in total reflection by the exit surface to all of the light rays incident on the entrance surface at incident angles in the range of 0° to 30° is in the range of 0.1% to 3%. However, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have the ratio of light rays reflected in total reflection by the exit surface to all of the light rays incident on the entrance surface at incident angles in the range of 0° to 30° be in the range of 0.1% to 3%, since it has been held that where the general conditions of a claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art. One would have been motivated to have the ratio of light rays reflected in total reflection by the exit surface to all of the light

rays incident on the entrance surface at incident angles in the range of 0° to 30° be in the range of 0.1% to 3%, for the purpose of maximizing or optimizing the overall transmission of the light-diffusing sheet, based on the intended application. *In re Aller*, 220 F.2d 454, 456, 105 USPQ 233, 235.

10. Claim 5 is rejected under 35 U.S.C. 103(a) as being unpatentable over Moshrefzadeh et al. in view of Arai.

Moshrefzadeh et al. in view of Arai discloses the invention as set forth above in Claim 1. Moshrefzadeh et al. in view of Arai further discloses that the number and angles of the facets on the sides of the wedge-shaped parts may be adjusted to adjust the diffusing properties of the light-diffusing sheet (See for example Figures 8A-B; Page 19, line 13-Page 20, line 12). Moshrefzadeh et al. in view of Arai does not explicitly disclose the ratio of light rays reflected in total reflection at least twice on the side surfaces of the wedge-shaped parts to all of the light rays perpendicularly incident on the entrance surface is 1% or above. However, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have the ratio of light rays reflected in total reflection at least twice on the side surfaces of the wedge-shaped parts to all of the light rays perpendicularly incident on the entrance surface be 1% or above, since it has been held that where the general conditions of a claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art. One would have been motivated to have the ratio of light rays reflected in total reflection at least twice on the side surfaces of the wedge-shaped parts to all of the light rays perpendicularly incident on the entrance surface be 1% or above, for the purpose of

optimizing the diffusing directions of the light-diffusing sheet, based on the intended application. *In re Aller*, 220 F.2d 454, 456, 105 USPQ 233, 235.

Conclusion

11. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

12. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Arnel C. Lavarias whose telephone number is 571-272-2315. The examiner can normally be reached on M-F 10:00 AM - 6:30 PM EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephone B. Allen can be reached on 571-272-2434. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Art Unit: 2872

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Arnel C. Lavarias
Primary Examiner
Group Art Unit 2872
6/27/08

/Arnel C. Lavarias/
Primary Examiner, Art Unit 2872



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/565,242	01/19/2006	Masahiro Goto	126735	9153
25944	7590	09/26/2008		
OLIFF & BERRIDGE, PLC P.O. BOX 320850 ALEXANDRIA, VA 22320-4850			EXAMINER LAVARIAS, ARNEL C	
			ART UNIT 2872	PAPER NUMBER
			MAIL DATE 09/26/2008	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Advisory Action Before the Filing of an Appeal Brief	Application No.	Applicant(s)	
	10/565,242	GOTO, MASAHIRO	
	Examiner	Art Unit	
	Arnel C. Lavarias	2872	

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED 16 September 2008 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. ☒ The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:

- a) ☒ The period for reply expires 3 months from the mailing date of the final rejection.
b) ☐ The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.

Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. ☐ The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. ☐ The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
(a) ☐ They raise new issues that would require further consideration and/or search (see NOTE below);
(b) ☐ They raise the issue of new matter (see NOTE below);
(c) ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
(d) ☐ They present additional claims without canceling a corresponding number of finally rejected claims.

NOTE: _____. (See 37 CFR 1.116 and 41.33(a)).

4. ☐ The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. ☐ Applicant's reply has overcome the following rejection(s): _____.
6. ☐ Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. ☐ For purposes of appeal, the proposed amendment(s): a) ☐ will not be entered, or b) ☐ will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
The status of the claim(s) is (or will be) as follows:
Claim(s) allowed: _____.
Claim(s) objected to: _____.
Claim(s) rejected: 1-8.
Claim(s) withdrawn from consideration: _____.

AFFIDAVIT OR OTHER EVIDENCE

8. ☐ The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. ☐ The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. ☐ The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. ☒ The request for reconsideration has been considered but does NOT place the application in condition for allowance because:
See Continuation Sheet.
12. ☐ Note the attached Information *Disclosure Statement*(s). (PTO/SB/08) Paper No(s). _____.
13. ☐ Other: _____.

/Arnel C. Lavarias/
Primary Examiner, Art Unit 2872

Continuation of 11. does NOT place the application in condition for allowance because: Applicant's remarks and arguments are noted. However, they were not found persuasive. In response to applicant's arguments, the recitation "light-diffusing sheet" has not been given significant patentable weight because the recitation occurs in the preamble. A preamble is generally not accorded any significant patentable weight where it merely recites the purpose of a process or the intended use of a structure, and where the body of the claim does not depend on the preamble for completeness but, instead, the process steps or structural limitations are able to stand alone. See *In re Hirao*, 535 F.2d 67, 190 USPQ 15 (CCPA 1976) and *Kropa v. Robie*, 187 F.2d 150, 152, 88 USPQ 478, 481 (CCPA 1951). Further, in response to applicant's argument that the references fail to show certain features of applicant's invention, it is noted that the features upon which applicant relies (i.e., light being transmitted through the wedge-shaped parts) are not recited in the rejected claim(s). Although the claims are interpreted in light of the specification, limitations from the specification are not read into the claims. See *In re Van Geuns*, 988 F.2d 1181, 26 USPQ2d 1057 (Fed. Cir. 1993).

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
18 January 2001 (18.01.2001)

PCT

(10) International Publication Number
WO 01/04701 A1

(51) International Patent Classification⁷: **G03B 21/62**

(US). **RADIYATH, Ragu**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(21) International Application Number: **PCT/US99/27250**

(22) International Filing Date:
17 November 1999 (17.11.1999)

(74) Agents: **MILLER, William, D.** et al.; 3M Innovative Properties Company, Office of Intellectual Property Counsel, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(25) Filing Language: **English**

(26) Publication Language: **English**

(30) Priority Data:
09/348,809 7 July 1999 (07.07.1999) **US**

(71) Applicant: **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(81) Designated States (*national*): AE, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

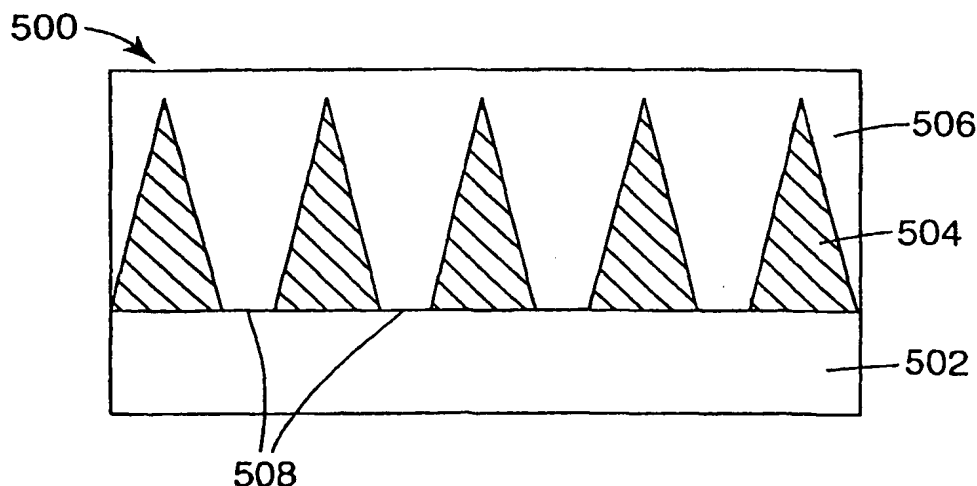
(72) Inventors: **MOSHREFZADEH, Robert**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). **THOMAS, Patrick**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). **NELSON, John**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). **HODAPP, Ted**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). **CHOU, Hsin-Hsin**; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). **POKORNY, Richard**; P.O. Box 33427, Saint Paul, MN 55133-3427

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— With international search report.

[Continued on next page]

(54) Title: **REAR PROJECTION SCREEN USING INTERNAL REFLECTION AND ITS PRODUCTION**



(57) Abstract: An optically dispersing film for a rear projection system includes reflecting surfaces disposed so as to reflect light passing therethrough into at least one dispersion plane. The reflecting surfaces are formed by structures, of a first refractive index, disposed within a layer of material having a second refractive index. The structures have light absorbing bases at the viewing side of the film. In some embodiments, the reflecting surfaces are disposed at one or more angles so as to reflect light into a number of different directions. In other embodiments, the layer of material having the second refractive index includes diffusing particles that diffuse the light. The film permits the asymmetric dispersion of image light in a rear projection system, so that the light may be selectively directed towards the viewer.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

REAR PROJECTION SCREEN USING INTERNAL REFLECTION AND ITS PRODUCTION

Background

The present invention is directed generally to a rear projection screen and more particularly to a rear projection screen that incorporates totally internally reflecting structures to disperse the light passing through the screen.

Rear projection screens are generally designed to transmit an image projected onto the rear of the screen into a viewing space. The viewing space of the projection system may be relatively large (e.g., rear projection televisions), or relatively small (e.g., rear projection data monitors). The performance of a rear projection screen can be described in terms of various characteristics of the screen. Typical screen characteristics used to describe a screen's performance include gain, viewing angle, resolution, contrast, the presence of undesirable artifacts such as color and speckle, and the like. It is generally desirable to have a rear projection screen that has high resolution, high contrast and a large gain. It is also desirable that the screen spread the light over a large viewing space. Unfortunately, as one screen characteristic is improved, one or more other screen characteristics often degrade. For example, the horizontal viewing angle may be changed in order to accommodate viewers positioned at a wide range of positions relative to the screen. However, increasing the horizontal viewing angle may also result in increasing the vertical viewing angle beyond what is necessary for the particular application, and so the overall screen gain is reduced. As a result, certain tradeoffs are made in screen characteristics and performance in order to produce a screen that has overall acceptable performance for the particular rear projection display application.

Thus, there remains a need for screens that have improved overall performance while meeting the minimum performance criteria necessary for the rear projection display application in which the screen is used.

Summary of the Invention

Generally, the present invention relates to a light dispersing film for a rear projection screen and its method of manufacture. The film disperses light passing

therethrough by reflecting the light off reflecting surfaces disposed within the film. The reflecting surfaces are formed at the surfaces of structures within the film.

In one particular embodiment, the light dispersing film includes a first layer formed from a first material having a first refractive index, the first layer having first and second
5 opposing sides and a first optical axis normal to the first side. The first layer includes structures formed from a second material having a second refractive index smaller than the first refractive index. The structures have bases at the second side with one or more side walls extending towards the first side. First internal reflecting surfaces are formed by
10 interfaces between the first and second materials. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. The first internally reflecting surfaces form reflecting units that asymmetrically disperse light through respective optically transmitting areas. The first reflecting surfaces form surfaces disposed at at least two angles relative to the first optical axis.

In another particular embodiment, the light dispersing film includes a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side. The first layer
15 includes structures formed from a second material having a second refractive index smaller than the first refractive index. The structures have bases at the second side with one or more side walls extending towards the first side. First internal reflecting surfaces are
20 formed by interfaces between the first and second materials. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. The first internally reflecting surfaces form reflecting units that asymmetrically disperse light through respective optically transmitting areas. The first
25 reflecting surfaces are disposed to reflect light to selected directions within a dispersion plane.

In another particular embodiment, the light dispersing film includes a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side. The first layer
30 includes structures formed from a second material having a second refractive index smaller than the first refractive index. The structures have bases at the second side with one or

more side walls extending towards the first side. First internal reflecting surfaces are formed by interfaces between the first and second materials. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. The first reflecting surfaces form surfaces disposed at two or more angles relative to the optical axis. All light reflected by the first reflecting surfaces is reflected at dielectric-dielectric interfaces.

In another particular embodiment, a film for a rear projection screen includes a substrate layer, having a first substrate layer side. Structures, formed from a first material having a first refractive index, are disposed with structure bases on the first substrate layer side. Sidewalls of the structures extend in directions away from the substrate. Structure bases are formed of light absorbing material. Clear areas are defined on the first substrate layer side between the structure bases. An overlayer, formed from a second material having a second refractive index larger than the first refractive index, is disposed over the structures and the clear areas of the first substrate layer side. Interfaces between the overlayer and the sidewalls form internally reflecting surfaces for light propagating within the overlayer towards the substrate in a direction substantially perpendicular to the substrate.

In another particular embodiment, a light diffusing film for a rear projection screen includes a first layer formed from a first material having a first refractive index, having first and second opposing sides and an optical axis normal to the first side. The first layer includes structures formed from a second material having a second refractive index smaller than the first refractive index. The structures have bases at the second side with one or more side walls extending towards the first side to define first reflecting surfaces. The structure bases include a light absorbing material and optically transmitting areas of the second side are defined between the structure bases. A bulk diffuser is disposed to disperse light passing through the optically transmitting areas of the second side.

In another particular embodiment, a light dispersing film for a rear projection screen includes a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side. The first layer includes structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side

with at least two side walls extending towards the first side. Internal reflecting surfaces are formed by interfaces between the first and second materials. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. At least one structure has at least one of the two sidewalls disposed at an angle selected to be parallel to diverging light passing through the film from an image light source positioned on the first optical axis.

In another particular embodiment of a light dispersing film, the film includes a first film having first and second opposing sides. the first film has a first refractive index within a first refractive index range. The first film includes structures formed from a structure material having a second refractive index smaller than the first refractive index range. The structures have bases at the second side with one or more side walls extending towards the first side. First internal reflecting surfaces are formed by interfaces between the structure material and the material of the first film. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. The first refractive index of the first film proximate the first side is different from the first refractive index of the first film proximate the second side.

In another particular embodiment, the light dispersing film includes a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side. The first layer includes structures formed from a second material having a second refractive index smaller than the first refractive index. The structures have bases at the second side with one or more side walls extending towards the first side. Metal coatings are disposed on at least portions of the side walls between the first and second materials to form first reflecting surfaces. The structure bases include a light absorbing material, and optically transmitting areas of the second side are defined between the structure bases. The first reflecting surfaces form reflecting units that asymmetrically disperse light through respective optically transmitting areas. A bulk diffuser is disposed within the first material to disperse light passing through the optically transmitting areas of the second side.

A particular method for manufacturing an optical film includes casting and curing structures on a substrate, the structures being formed from a first material having a first refractive index and with optically absorbing bases on the substrate, and open substrate

areas being defined between adjacent structures on the substrate. The method also includes overcoating the structures and the open substrate areas with a second material having a second refractive index greater than the first refractive index, so as to form reflecting surfaces at interfaces between the first and second materials. The reflecting surfaces are disposed to reflect light, propagating through second material substrate in a direction substantially parallel to an optical axis of the film, towards open substrate areas.

Another particular method of forming an optical film includes forming grooves on a first side of a film of first material having a first refractive index, with open areas of the first side between the grooves. The method also includes forming an optical scatterer on the open areas of the first side, and filling the grooves with a second material having a second refractive index smaller than the first refractive index, the second material being optically absorbing.

Another particular method of forming an optical film includes casting and curing structures on a substrate, the structures being formed from a first material and with optically absorbing bases on the substrate, and open substrate areas being defined between adjacent structures on the substrate. The method also includes disposing a metallic layer over at least part of the structures to form reflecting surfaces and overcoating the metallic layer and the open substrate areas with a second material. The reflecting surfaces are disposed to reflect light, propagating through second material substrate in a direction substantially parallel to an optical axis of the film, towards open substrate areas.

The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed description which follow more particularly exemplify these embodiments.

Brief Description of the Drawings

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. 1 illustrates a rear projection display;

FIGs. 2A and 2B illustrate cross-sectional views of particular embodiments of rear projection displays;

FIG. 3 shows curves of optical gain plotted against angle of view, for vertical and horizontal angles;

FIGs. 4A and 4B illustrate one embodiment of a light dispersing screen;

FIGs. 5A and 5B illustrate different light dispersing layers;

FIG. 5C illustrates a partially fabricated light dispersing layer;

FIGs. 6A and 6B respectively illustrate gain profiles of the light dispersing layer illustrated in FIG. 6A;

FIGs. 7A and 7B illustrate a light dispersing layer having curved reflecting structures according one embodiment of the present invention;

FIG. 8A and 8B illustrate an embodiment of a light dispersing layer having faceted reflecting structures according to an embodiment of the present invention;

FIGs. 9 and 10 illustrate different embodiments of light dispersing layers according to the present invention;

FIG. 11 illustrates another embodiment of a light dispersing layer according to the present invention;

FIGs. 12 and 14 illustrate additional embodiments of light dispersing layers of the present invention, with light dispersion in two dimensions;

FIGs. 13A and 13B illustrate cross-sections through the light dispersing layer of FIG. 12;

FIG. 15 illustrates an embodiment of a light dispersing layer having an overcoat with a varied refractive index according to an embodiment of the invention;

FIG. 16 illustrates an embodiment of a light dispersing layer having a scattering interface according to an embodiment of the invention;

FIG. 17 illustrates an embodiment of a light dispersing layer having a scattering surface according to an embodiment of the invention;

FIG. 18 illustrates another embodiment of a light dispersing layer according to the present invention;

FIG. 19 illustrates an expanded view of a low-refractive index structure of the embodiment shown in FIG. 16;

FIGs. 20A-20C illustrate manufacturing steps in a method for manufacturing a film according to the present invention;

FIG. 21A illustrates the absorption of stray light by reflecting structures;

FIG. 21B illustrates the redirection of stray light by reflecting structures;

FIG. 22 illustrates an embodiment of a light dispersing layer having a refracting structures positioned to refract light passing through open areas, according to an embodiment of the invention; and

FIG. 23 illustrates method steps for forming a metallically reflecting film according to an embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

Detailed Description

The present invention is generally applicable to a number of different screen assemblies and is particularly suited to screen assemblies used in rear projection systems. In particular, the present invention is advantageous in applications where the most likely position of the viewer, or viewers, is known: the invention is useful in directing light from all portions of the screen to the most likely viewer position, to increase brightness uniformity across the screen.

The rear projection display 100 is described with reference to FIGs. 1 and 2. The display includes an image projector 102 that projects an image onto the rear side of a screen 104. The image is transmitted by the screen 104 so that a viewer 106, located at some point beyond the screen 104, can see the image projected through the screen 104. The rear projection display 100 may be, for example, one or more rear projection

televisions, or one or more rear projection computer monitors, or any other rear projection displaying apparatus.

In accordance with one embodiment of the invention, an image projector 102, for example a liquid crystal display-based light projector, or any other suitable type of image projector, can be used in the rear projection display 100 to project an image onto the rear surface of the screen assembly 104. The rear projection display may vary in size from relatively small data monitors, to large screen televisions and video walls. The projection display 100 may also rely on a folded image projection path within its housing, such as the various projection systems described in European Patent Application EP783133, entitled "Projecting Images", the contents of which are incorporated herein by reference. As will be appreciated from the descriptions below, such systems particularly benefit from the use of the various screen assemblies described herein below.

A more detailed description of the various screen characteristics is now provided. One important screen characteristic is gain. The gain of a screen represents the screen's brightness as a function of viewing angle. The gain is typically calibrated using an ideal Lambertian reflector with the gain of the ideal Lambertian standard set at 1 for all angles. The peak gain of a screen (or screen element) corresponds to the highest gain at some angle. For example, the peak gain of a bulk diffuser screen, illuminated from behind at normal incidence, is typically observed for the light transmitted through the screen at an angle normal to the screen surface.

Another important screen characteristic is viewing angle. The viewing angle of a screen, as used herein, is the angle at which the gain of the screen drops to half of the peak gain. In many situations, the viewing angle corresponds to the difference between the angle of maximum luminance and the angle at which the luminance of the transmitted image drops to half of the maximum luminance of the screen. Typically the maximum luminance occurs for light transmitted in a direction normal to the screen surface.

The particular application of a rear projection system determines the desired viewing angle. It is typically advantageous to control the angular dependence of the screen's luminance by directing light to that region where the viewer is most likely to be situated. For example, where the rear projection display is a data monitor, the viewer is typically positioned centrally relative to, and within approximately one to three feet from,

the screen. The viewer's eyes may be positioned above a line normal to the center of the screen, but the viewer typically does not view the screen from a distance as much as one or two feet above the screen. Furthermore, for reasons of privacy or security, it may be desirable to reduce the luminance emerging from the screen at an angle of e.g. 30° or more relative to a normal to the screen. This reduces the possibility that someone positioned far away from the axis of the screen, and perhaps having no authority to view the contents of the screen, sees the information on the screen.

Another application for a rear projection screen is in a home television system, where it is generally desired to direct the angular dependence of the screen's luminance over large horizontal angles, since it is common for viewers to be seated at a position other than directly in front of the television screen. On the other hand, few viewers view the television screen from a position significantly above or below the screen, and therefore it is commonly desired to reduce the screen's viewing angle in the vertical direction. Accordingly, the preferred viewing angles for a television are typically smaller in the vertical direction than in the horizontal direction. In certain applications, the vertical divergence of the light from a television screen may preferably be tilted downwards relative to a normal from the television screen. This accommodates, for example, viewers watching the television from the floor. In this example, it is not as important to deflect light upwards from the television screen, since viewers typically do not stand to watch television for any length of time.

An important characteristic of a screen is its ability to avoid unwanted color or speckle effects. In certain screens color may be observed as a random pattern of differently colored, pixel-like spots on the screen. Such color artifacts typically result from wavelength-dependent effects, such as scattering in which different wavelengths are scattered in different directions or with different efficiency. As a result of the wavelength-dependent effects, different colors may become physically separated and observable on the viewer side of the projection screen. Scattering surfaces, such as matte-finished surfaces are particularly susceptible to problems of speckle and color.

The resolution provided by the rear projection screen is becoming more important as rear projection displays are used in applications with increasingly higher resolution requirements, for example high definition television. The resolution of a screen is generally

defined as a measure of the finest detail that can be distinguished in an image projected on the screen.

Considering now the illustration of FIG. 2A, the image light 110 produced by the image projector 102 is directed to the screen assembly 124. The screen assembly 124 typically includes several different layers for controlling the image seen by the viewer, including a dispersing layer 134 and a glass plate 136 to provide support. The dispersing layer 134 disperses, or diffuses, light passing through a particular point of the screen into a cone angle, so that a viewer on the far side of the screen can detect image light from that particular point. It will be appreciated that the dispersing layer 134 typically disperses light from all points across the screen so that the viewer can see the entire image projected onto the screen assembly 124 by the image projector 102.

Here, the term “disperse” is employed to refer to any process that changes the direction of the image light, for example scattering, diffusion, refraction or reflection, or any other approach, which produces a viewing angle in one or more directions. The use of the term does not imply wavelength dependent characteristics. The term “dispersion angle” is the angle through which light is dispersed, e.g. scattered, refracted or reflected, relative to the incident direction. Dispersion may be symmetric, or isotropic, as is typically obtained using a bulk diffuser. Dispersion may also be asymmetric, or non-isotropic, for example where the viewing angle in the vertical direction is different from the viewing angle in the horizontal direction. A “dispersion plane” refers to a geometric plane of dispersion. For example, light that is dispersed by a film in a horizontal direction may be referred to as being dispersed within a horizontal dispersion plane, or in a direction parallel to horizontal dispersion plane.

The on-axis ray of light 112 is dispersed by the dispersing layer 134 to produce a viewing angle of 2θ . The off-axis light rays 110 from the image projector 102 illuminate the edge of the screen assembly 124, and are separated from the on-axis ray 112 by an angle of α . When the off-axis rays 110 pass through the dispersing layer, they are dispersed by $\pm\theta'$ about a ray 111 that is at an angle α relative to a screen normal. The angle θ' may or may not be equal to angle θ , as the specifics of the scattering event will depend upon other optical properties of the rear projection screen.

Another screen assembly 104 is illustrated in FIG. 2B, in which light 110 from the image projector 102 is collimated by a Fresnel lens 113 before being incident on the dispersing layer 114. The dispersing layer 114 is supported on a support layer 116, which may be, for example, a glass screen. In this case, the dispersed light transmitted through the edge of the screen 104 is dispersed about a ray 115 that is normal to the screen. One advantage of the screen assembly 104 over the screen assembly 124 without any Fresnel lens is that the angle through which light from the edge of the screen has to be dispersed in order to be detected by an on-axis viewer is reduced. Since the intensity of dispersed light generally decreases with increased angle, the image seen by a viewer on the screen assembly 104 having a Fresnel lens typically appears to be more uniformly intense across the screen than where no Fresnel lens is used.

One example of a desired gain characteristic for a television screen is illustrated in FIG. 3. The figure illustrates two curves, 302 and 304, that relate gain to angle of viewing, θ , as might be obtained for a screen used in a television. The broader curve 302 illustrates the gain, G , as a function of angle, θ , in a horizontal direction. In other words, curve 302 describes the brightness of the screen perceived by a viewer as the viewer moves sideways away from the screen. The horizontal viewing angle, θ_H , is the angle at which the luminance of the horizontally dispersed light falls to half of the maximum luminance.

The narrower curve 304 represents the dependence of the gain as a function of angle relative to the screen viewed in a vertical direction. As has been discussed above, it is typically desired in a television application that the image from the screen be directed vertically in a relatively narrow range of angles in order to avoid throwing away light that would otherwise illuminate the floor and ceiling. This increases the screen brightness perceived by viewers located in the expected viewing zone. The vertical viewing angle, θ_v , the angle at which the light intensity is one half of the maximum intensity, is less than the horizontal viewing angle, θ_H .

Accordingly, it should be appreciated that there are several applications for rear projection display screens in which the dispersion is asymmetric, in order to provide a vertical viewing angle, θ_v , different from the horizontal viewing angle, θ_H . Also, the viewing angle in one direction, for example the vertical direction, need not be symmetric about the axis through the screen. For example, the gain in the vertical direction may fall

more rapidly with increasing angle above the screen axis than for decreasing angle below the screen axis, as is shown for curve 306, which has its peak gain at $\theta = 0^\circ$, but which sheds more light downwards than upwards.

5 An important measure of screen performance is contrast. Contrast is generally the ratio of luminance of a projected white image to that of a projected black image. As such, numerical contrast numbers are dependent on the light source and the imaging optics. The contrast ratio tends to increase with increasing screen brightness and as the projected black image is made blacker. In one instance, contrast may be measured in terms of the dynamic range of the system. The dynamic range is a measure of the contrast ratio in the absence of ambient light. When a projection display is used in the presence of ambient light, some of the ambient light may be reflected from the screen. The reflected light typically includes both specular and diffuse components. The ambient reflection tends to decrease the contrast of the screen. Thus, if the screen is used in the presence of ambient light, the contrast ratio is also dependent upon the ability of the screen to absorb the ambient light: it is particularly desirable to reduce the amount of ambient reflection from the screen. Therefore, the amount of ambient reflectance provides another useful measure of screen performance.

One approach to dispersing the light, discussed in U.S. Patent 5,768,014 and illustrated in FIG. 4A, is to use a single layer screen 400, having a front surface Fresnel lens 402 on the input side that receives the light from the image light source. A number of refractive prisms 404 are provided on the exit surface 406 of the screen. The prisms 404 are shaped as isosceles triangular prisms, their bases flush with exit surface 406. The refractive index of the prisms 404 is lower than the refractive index of the surrounding bulk material 408. Absorbing material within the prisms 404 absorbs any light that passes into the prisms 404. The prisms 404 are arranged in layers 410, 412, and 414, with the position of the prisms 404 staggered between each layer. The clear portions 416 of the exit surface 406, between the prisms 404, are provided with a fine-mat-surface that acts as a surface scatterer.

The operation of the screen 400 is explained with reference to FIG. 4B, which shows a section through the screen 400. Light 420 from the image light source is incident on the Fresnel lens 402, which collimates the light along the direction of propagation. The

light then propagates towards the exit surface 406. Some of the light intercepts the interface 422 between a prism 404 and the bulk material 408. The angle of the prism apex, θ , and the difference between the refractive indices of prism 404 and the bulk material are selected so that the light is totally internally reflected at the prism interface 422 towards the clear portion 416 of the exit surface 406. The light propagates through the exit surface 406 at an angle to the surface normal, and suffers some scattering by the fine-mat-surface. Some of the light collimated by the Fresnel lens 402 is directly incident on the clear portion 416, and propagates out of the screen 400 substantially in the normal direction shown by the ray 424. Thus, total internal reflection by the prisms 404 is used to disperse the light in the horizontal direction, while the fine-mat-surface provides isotropic scattering into both the vertical and horizontal directions. The bases of the prisms 404 present light absorbing material to the viewing surface of the screen 400. Absorption of ambient light by the prism bases provides the screen contrast.

Several problems with the screen 400 remain unaddressed in U.S. Patent 5,768,014. One problem is the use of the surface scatterer. If there is no isotropic scattering at the exit surface of the screen 400, then the light emerges only along three distinct directions, labeled A, B, and C. Consequently, the horizontal gain of the screen 400 has three peaks, one at zero degrees, (direction A) and the other two peaks positioned symmetrically about the center peak, corresponding to directions B and C. In order to provide a relatively smooth horizontal gain curve, and to prevent the gain profile from being dominated by the three peaks, there must be a large amount of scattering at the fine-mat-surface, i.e. the fine-mat-surface must scatter light through a relatively large angle. However, the use of a surface scatterer, particularly a surface scatterer having a sufficiently high degree of scattering to produce the vertical viewing angle and to smooth out the horizontal gain profile, results in speckle and color problems in the viewed image. The speckle resulting from a surface scatterer may be reduced by increasing the degree of scatter imparted by the scatterer. However, the requirement to increase light scattering to reduce speckle may run contrary to the amount of scatter required to produce the desired horizontal and vertical viewing angles.

Another drawback with using a surface scatterer is that the scattering properties are compromised if the film is laminated to another film. The effect of the lamination is to

reduce the refractive index difference experienced by light as it passes out of the high refractive index material, and so the scattering is reduced. This may be particularly important if the surface scatterer is the only mechanism in the film for smoothing out the horizontal gain profile. Accordingly, the use of the fine-mat-surface may limit the range of performance of the screen.

Another problem with the screen 400 is that transmission through the film may be reduced if the light is internally reflected more than once. Therefore, the spacing between adjacent prisms that achieves maximum transmission is sufficiently large that light is not reflected by more than one prism. Thus, for maximum transmission, the spacing between prisms is dependent on the required viewing angle: if a larger horizontal viewing angle is required, then the inter-prism spacing is increased. However, increasing the inter-prism spacing reduces the ratio of the black area on the screen, and so the screen contrast is reduced. Thus, screen contrast is not independent of screen transmission or viewing angle.

Another problem with the screen 400 is that the method for manufacturing a film is complex, which results in increased manufacturing costs.

An important advantage of the present invention is that the dependence of the film on the use of a surface scatterer is reduced. Consequently, the present invention may be used to substantially reduce the non-uniformity of the gain profile resulting from internal reflection, thus permitting different viewing angles to be established in the horizontal and vertical directions without adversely affecting other characteristics of the film. Additionally, the limitations on the screen contrast may be reduced, thus permitting the screen contrast to be increased without limiting the viewing angle or the screen transmission. An embodiment of the present invention is a screen whose internally reflecting surfaces are disposed to reduce the large peaks in the gain curve discussed above with respect to the screen 400, i.e. to reduce the non-uniformities in the gain profile. The invention permits the designer to select reflection of image light in different directions within a dispersion plane.

One particular embodiment of the present invention is illustrated in FIG. 5A. A film 500 includes a substrate layer 502 having, on one surface, triangular structures 504 that absorb light and that have a relatively low refractive index. The structures are separated, at their bases, by clear areas 508. A layer 506 of high refractive index material overlies the

structures 504, filling the spaces between adjacent structures 504. The high refractive index layer 506 may be loaded with diffuser particles to act as a bulk diffuser. Bulk diffusers do not suffer from the same problems as the fine-mat-surface mentioned above. First, the speckle problem is reduced because the bulk diffuser breaks up the coherence of the light passing through the screen. Second, the color problem is reduced because multiple-scattering events tend to average out the wavelength dependence of the scattering event. Third, the bulk diffuser can be laminated to other layers without adversely affecting its light dispersing properties.

The structures 504 may be formed as short structures and arranged in a checkered pattern in a film, for example like the pattern illustrated in FIG. 4A. The structures may also be formed as ribs that extend across substantially the entire width of the film, or as two dimensional structures that have reflective surfaces arranged to reflect light in directions parallel to more than one dispersion plane.

Another type of screen layer 520 is illustrated in FIG. 5B. Here, the substrate 502 and the structures 504 are the same as in the first dispersing layer 500. A layer of bulk diffuser 522 is positioned at the bottom of the valleys between structures 504, over the clear areas 508. A top layer 524 of high refractive index material is positioned over the structures 504 and bulk diffuser layer 522. In another embodiment (not illustrated) the density of diffusing particles may be graded so that there is less diffusion close to the top of the structures and there is increased diffusion close to the structure bases. Also, the density of diffusing particles may be graded to produce increased diffusion close to the top of the structures and less diffusion close to the structure bases.

A dispersing layer 500 was manufactured by forming the structures 504 as rib-like structures across a polycarbonate substrate film (DE6-2 manufactured by Bayer) using a cast and cure method, to produce the article shown in FIG. 5C. The structures 504 were formed from a UV cured urethane-acrylate resin (photomer 6010) that cured to a refractive index of about 1.51. The resin was mixed with carbon black to a level of about 1500 ppm by weight. The structures were formed with a pitch of about 100 μm : the base of each structure 604 had a width of 80 μm , and the clear area 608 had a width of 20 μm . The apex angle, also known as inclusion angle, of each structure 604 was 30°, and the height was about 150 μm .

The high refractive index layer 506 was formed by planarizing using a bead-loaded resin. The resin was a UV curable, brominated acrylate blend with a cured refractive index of 1.59, and was loaded with acrylate-polystyrene beads to provide isotropic diffusion. The average bead diameter was about 5 μm , and the bead refractive index was 1.54. A release
5 liner was in place during the planarization and curing. The finished article was as the dispersing layer 500 shown in FIG. 5A. Different bead loading levels of 0%, 3%, 7% and 15% by weight were used to add different amounts of isotropic scattering.

Light incident on the interfaces between the high refractive index layer 506 and the structures 504 is largely totally internally reflected, since the angle of incidence on the
10 interface is greater than the critical angle, θ_c , given by $\theta_c = \sin^{-1}(n_L/n_H)$ where n_L is the refractive index of the structure 504 and n_H is the refractive index of the high index layer 506. However, some of the absorbing particles may be present at the interfaces between the structures 504 and the high index layer 506, which may prevent total internal reflection from taking place. Accordingly, a large fraction of the light incident on the interfaces
15 between the between the structures 504 and the high index layer 506 may be totally internally reflected, while a small fraction of the light is not totally internally reflected, and may be partially reflected or absorbed. Light reflected from the interfaces is referred to as being internally reflected. Internal reflection arises predominantly from the interface between two dielectric materials.

The horizontal and vertical gain of the light dispersing layer 500 are shown in FIGs. 6A and 6B respectively, for collimated light incident on the input face of the light
20 dispersing layer 500 at normal incidence. In FIG. 6A, the top curves 602 and 604 show the gain in the horizontal direction where the bead loading was 0%. The other curves 606, 608 and 610 respectively show the horizontal gain for bead loading of 3%, 7% and 15%. It can
25 be seen that there is a dip in the gain at about 20° for all values of isotropic scattering, while there is an off-center peak at about 40°. This peak is caused by light that is internally reflected by the structures 504, and corresponds to light emitted in the direction "B" shown in FIG. 4B. The dip and off-center peak are particularly noticeable at low values of bead
30 loading, and are normally deleterious to the operation of the screen. The viewer's preference is typically for the screen brightness to fall off continuously as angle of viewing is increased from normal incidence viewing, rather to fall to a low value and then rise again

as the angle increases. It was also found that the amount of light transmitted by the dispersing layer 600 was not significantly affected by the degree of bead loading: the transmission with 0% loading was less than 10% greater than the transmission when the loading was 15%.

5 The equivalent set of vertical gain curves is shown in FIG. 6B, where curves 622, 624, 626, 628 and 630 correspond to horizontal gain curves 602, 604, 606, 608 and 610 respectively. The vertical gain is reduced, and the vertical viewing angle is increased, as the amount of isotropic scattering is increased, with the result that the vertical viewing angle is at its highest when the horizontal gain curve is at its smoothest. It will be appreciated that
10 the dispersing layer 500 suffers from a problem similar to that of the screen 400 in that a high degree of isotropic scattering is required to ensure that the horizontal gain is smooth. However, since this screen uses bulk diffusion, rather than surface scattering, this embodiment has advantages of reduced speckle and color separation compared to the screen 400, and it can be laminated to another layer without its light scattering
15 characteristic being adversely affected.

A number of approaches may be used to reduce the formation of the dip and the off-center peak in the gain of a screen that uses internally reflecting structures for dispersing light. Some of these approaches use reflecting structures that present reflecting surfaces lying at more than one angle to an axis passing through the screen. For example,
20 different structures may have different apex angles, or a single structure may have a faceted reflecting surface or a curved reflecting surface.

One particular embodiment of an internally-reflecting, dispersing layer 700 is illustrated in FIG. 7A. Light absorbing structures 704 made from a low refractive index material are positioned on a surface of a substrate 702. The structures 704 are overcoated
25 with a high refractive index layer 706 that may be loaded with diffusive beads to provide dispersion in both the horizontal and vertical directions. Open areas 708 lie between the bases of the structures 704. The internally reflecting surfaces 710 of the structures are not straight, as in previously described embodiments. Instead, the surfaces 710 are curved. As a result, and ignoring any isotropic dispersion for the moment, the light that is internally
30 reflected by the structures 704 passes through the open areas 708 in a range of different directions. This contrasts with the embodiment illustrated, for example in FIG. 4A, in

which the internally reflected light passes through the clear portions 416 in a single direction, resulting in the large off-center gain peak.

This is illustrated in FIG. 7B, which shows collimated light 712 entering the valley between two adjacent structures 704. The structure surfaces 710 in this example have a parabolic shape, but any suitable curve may be used for the surfaces. The portion of the light that is incident on the top portion of the structure 704 is reflected at a highly glancing angle, and so is deviated through a relatively small angle and emerges from the substrate 702 at an angle of α_1 . The surface 710 close to the base 714 of the structure 704 lies at a larger angle relative to the direction of the incoming light than at the top of the structure 704, and so the light incident on the surface 710 close to the base 714 is reflected at a larger angle, and emerges from the substrate 702 at an angle $\alpha_2 > \alpha_1$. Therefore, even without considering isotropic dispersion from a bulk diffuser, the internally reflected light emerges from the dispersing layer 700 over a range of angles, and the off-center gain peak may be reduced. Isotropic dispersion from, for example, dispersing beads disposed within the high refractive index layer 706, may be used to disperse the emerging light further. Since the curved surfaces 710 disperse the emerging light over a range of angles, the degree of dispersion required of the diffuser to smooth out the off-center peak and remove the dip is reduced. Therefore, there is less need to compromise on the value of the vertical viewing angle.

Another particular embodiment is illustrated in FIG. 8A. Here, the dispersing layer 800 is formed from light absorbing, internally reflecting structures 804 positioned on a surface of a substrate 802. The valleys between adjacent structures 804 are filled with a high refractive index material 806, and clear areas 808 lie between the bases 812 of the structures 804. The internally reflecting surface 810 of the structure 804 includes two or more rectilinear portions, or facets, lying at different angles to each other. In the particular example illustrated, the surface 810 is formed from three rectilinear portions 810a, 810b and 810c. The angle of incidence of light on the rectilinear portions 810a, 810b, 810c increases for the portions increasingly closer to the structure base. Accordingly, the internally reflected light emerges from the substrate 802 over a range of angles, even without any bulk diffusion or other isotropic dispersion. Therefore, a structure having a surface 810 with rectilinear portions may be formed to spread the light horizontally over a

range of angles, and thus reduce the effect of both the dip and the off-center peak on the horizontal gain profile. Accordingly, the requirement to provide isotropic dispersion is reduced in this embodiment and, therefore, there is less need to compromise on the value of the vertical viewing angle.

5 In this particular embodiment and the like, the angle of each facet can be chosen so that the undeflected and internally reflected light emerges from the high refractive index material at equally spaced or progressively increasing angles. Furthermore, the length of each facet may be selected so that the amount of light emerging at the different angles is equal, is progressively smaller for increasing emerging angles, or has some
10 other selected characteristic. This embodiment permits the gain profile to substantially eliminate dips and off-center peaks when an appropriate diffuser is provided between the bases 812, or throughout the high index material 806.

This is further illustrated in FIG. 8B which shows, in schematic form, the reflecting surfaces 820a and 820b formed by a structure 810 having two facets. The
15 figure shows the paths taken by three rays of light 822, 824 and 826 incident at different points on the reflecting surfaces 820a and 820b. The horizontal extent of each of the reflecting surfaces 820a and 820b is respectively w_1 and w_2 . The values of w_1 and w_2 may be equal, or may be set to be different, so that each reflecting surface 820a and 820b intercepts a different amount of the incident light.

20 The first ray 822 is incident on the top edge of the upper reflecting surface 820a, and passes through the lower surface 828 of the high index material 806 at an angle β_1 . The second ray 824 is incident close to the bottom edge of the upper reflecting surface 820a, and reflects off the upper reflecting surface 820a onto the lower reflecting surface 820b, and off the lower reflecting surface 820b through the lower surface 828 of the
25 high index material 806 where it emerges with an angle β_2 which is greater than β_1 . The third ray 826 is directly incident on the lower reflecting surface 820b, off which it reflects to emerge through the lower surface 828 of the high index material 806 at an angle β_3 which is greater than β_3 .

30 Light may, of course, pass through the screen 800 undeflected. Therefore, a film with structures having only two facets may, without considering the effects of a diffuser or scatterer, produce light that emerges in four different directions. A diffuser

or scatterer may be used to spread the light at each of these directions so as to reduce the off-axis peaks and to remove the gain dips.

An important advantage provided by the embodiments shown in FIGs. 7A and 8A is that light is effectively focused by the structures, so that the width of the clear space between adjacent structures may be reduced. Thus the clear area on the screen is reduced while the black area on the screen is increased, and so the overall screen contrast may be increased without a reduction in overall transmission or viewing angle.

The slope of the structures need not be highest at the top of the structure and lowest close to the structure base. Instead, the slope of the structure, i.e. the angle of its surface relative to the substrate, or the structure base, may be less for the structure surface closer to the top of the structure, and may be higher for the surface closer to the structure base.

Another particular embodiment is illustrated in FIG. 9, in which a number of light absorbing, internally reflecting structures 904 are provided on a substrate 902. The valleys between adjacent structures 904 are filled with a high refractive index material 906, and clear areas 908 lie between the bases 912 of the structures 904. The structures may have flat reflecting surfaces 910, although the surfaces 910 may also be curved or contain rectilinear portions. Different apex angles are used for different structures. For example, the apex angles of the structures 904a, 904b, 904c and 904d are all different. The position of the off-center gain peak and the gain dip are dependent on the apex angle of the internally reflecting structure. Accordingly, since the dispersing layer 900 has structures 904 having different apex angles, the internally reflected light emerges from the substrate 902 over a range of directions, if isotropic dispersion is ignored. Thus, the deleterious effects of the off-center gain peak and dip may be reduced and the requirement to provide isotropic dispersion is reduced in this embodiment. Therefore, there is less need to compromise on the value of the vertical viewing angle.

Unlike the embodiments illustrated in FIGs. 7A and 8A, the reflecting surface of each structure 908 presents only one angle to incident light, and so the light emerges from that structure only at one angle. However, the structures 908 may be made to be sufficiently small that a viewer's eye perceives light from a single pixel that has a dimension

sufficiently large to cover several structures having different apex angles. thus, the integrated effect is that light emerges from each pixel over a range of angles.

An increased apex angle results in the light reflected at the top of the structure 904 being displaced by a greater distance from the structure base as the light passes through the interface between the high index layer 906 and the substrate 902. Accordingly, the width, d, of the clear space 908 between a pair of adjacent structures 904 is preferably selected to permit the light reflected from the top of the structure 908 to pass through without a second reflection. Thus, the separation between structures 904c and 904d is selected to permit rays 914 and 916 to pass through the clear area 908a therebetween. Second internal reflections may be problematic because the angle of incidence on the reflecting surface 910 is greater than the first reflection, and so the second bounce onto a reflecting surface may be at an angle smaller than the critical angle, resulting in absorption losses. Furthermore, a second internal reflection increases the path length within the high index material layer 906 which may result in further losses if the layer 906 is loaded with diffusing particles.

On the other hand, since the contrast of the screen is dependent on the fractional area of the absorbing bases on the screen's viewing surface, the contrast of the screen may be increased if the structures are placed closer together. Accordingly, the pitch between adjacent structures may be varied in accordance with the aspect ratio of the structures. For those structures having an aspect ratio which results in the light intercepting the clear area close to the structure base, for example structures having a smaller apex angle, then the inter-structure spacing may be reduced. Also, where the structure aspect ratio results in the light intercepting the clear area further from the structure base, for example structures having a larger apex angle, then the inter-structure spacing may be increased.

The inter-structure spacing, or pitch, may be selected to be constant, or may vary between different structures. For example, the inter-structure spacing for different structures may be randomized. A film having a randomized inter-structure spacing may have structure apex angles selected according to the randomized spacing to optimize light transmission through the film.

This embodiment may be useful for reducing Moiré patterns, since the pattern of structures 904 has no fixed period. A Moiré pattern is an interference pattern that is generated as result of sampling frequency (the screen pitch) being less than twice the

frequency of the pattern being displayed (for example the pitch of the imager which is related to the pixel size). Another mechanism for generating Moiré patterns is when the sampling frequency (screen pitch) and the image frequencies are very close to each other and as a result they beat against each other. One way to eliminate a Moiré pattern, or at least make it less viewable, is to reduce the pitch of the screen so that the screen frequency is much more than the pixel frequency. Therefore, the Moiré pattern may be reduced where the period of the structure spacing is selected to be less than the size of the pixel. Also, the Moiré pattern may be reduced where the spacing between different structures is different, for example randomized.

Another embodiment is illustrated in FIG. 10. The dispersing layer 1000 includes internally reflecting structures 1004 positioned on a surface of a substrate 1002. The structures 1004 are formed from a material having a relatively low refractive index, and a layer 1006 of relatively high refractive index fills the valleys between the structures 1004. The base portion 1005 of each structure 1004 contains light absorbing material to enhance the contrast provided by the dispersing layer 1000. The remainder of each structure 1004 need not contain light absorbing material.

The light dispersing layer 1000 may also be provided with a Fresnel lens to collimate light from the image light source so as to be parallel to an axis between the image light source and the screen, or at least to partially redirect the light propagating between the image light source and the light dispersing layer. A first surface Fresnel lens may be used, but this approach suffers from the problems described earlier.

Another approach, using an embedded Fresnel lens is illustrated in FIG. 10. Embedded Fresnel lenses are discussed more fully in U.S. Patent Application Serial No. 09/229198, filed on January 13, 1999 and which is incorporated herein by reference. An embedded Fresnel lens is formed from a material having a relative high refractive index, and is embedded in a material of relatively low refractive index to permit refraction at the output surface of the Fresnel lens to substantially collimate or redirect the light. Therefore, this embodiment includes a layer 1020 of a material having a relatively low refractive index disposed above the high refractive index layer 1006. A Fresnel lens 1022 is disposed above the low index material layer 1020, with the surface 1024 of the Fresnel lens embedded in the low index material layer 1020.

A Fresnel lens having a second surface in air may be used with the present invention. Such Fresnel lenses typically suffer from a problem of ghost images that arise from off-axis reflections of light, as is described U.S. Patent Application Serial No. 09/229198. One particular advantage provided by the present invention is that the off-axis ghost image light may be incident on the structures at an angle below the critical angle, in which case the ghost image is absorbed, as illustrated in FIG. 21A. Stray light 2110 is incident on a structure 2104 at an angle less than the critical angle, and so a portion of the light passes into the structure 2104 where it is absorbed. The structure 2104 is drawn shaded in order to show passage of the light into the structure 2104. A portion of the light 2110 may be reflected as ray 2122, and be further incident on another structure 2104a, where another portion is absorbed. Thus, the structures may be used to absorb stray light entering the input side of the screen.

Another advantage is that the ghost image may be reflected back out of the screen through the input face, so that the ghost image never passes out to the viewer. This is illustrated in FIG. 21B, which shows stray light 2120 reflecting multiple times between two structures 2104, and being directed away from the viewer's side of the screen so that it does not pass out through the clear space 2108 between the structures 2104. Thus, the structures may also be used to redirect stray light that enters the input side of the screen.

Therefore, the present invention may be used to remove the ghost image that results from the use of a Fresnel lens, and may also be useful at reducing the amount of stray light that passes from the input side of a screen to the viewer's side of the screen.

It should be appreciated that Fresnel lenses, including first surface, and second surface Fresnel lenses, both embedded Fresnel lenses and Fresnel lenses with the second surface in air, may be used with the other embodiments described herein.

The reflecting, light absorbing structures may be arranged in different geometrical patterns, and may also be shaped to disperse light in more than one direction. Consider first the arrangement illustrated in FIG. 11, which is a perspective view of the embodiment illustrated in FIG. 6A, without the layer of high index material for clarity. The structures 604 are arranged in parallel, forming a rib-like arrangement, and are shaped for dispersing light in the x-direction only. For example, light ray 1102 passes through the substrate

without being deviated, while ray 1104 reflects off the surface 610 and propagates within the x-z plane with a direction component parallel to the x-axis.

The structures 604 need not be straight, and could be curved to direct light into desired directions.

5 Another embodiment is illustrated in FIG. 12, where a substrate 1202 has structures 1204 positioned on one surface 1206. A layer of high refractive index material may be disposed over the structures 1204 and the substrate, but this is not shown in order to simplify the illustration. There are clear areas 1208 between the structures 1204, where the light reflected by the structures 1204 passes into the substrate 1202. The structures 1204
10 are shaped to disperse light in two directions, namely within the x-z plane and within the y-z plane, i.e. so that the light travels with an x-direction component and a y-direction component respectively. Light ray 1210 is directly incident on a clear area 1208 and passes into the substrate without reflection. Light ray 1212 reflects off one of the faces 1216 facing the x-direction, and emerges from the substrate 1202 travelling in the x-z plane, with
15 a direction component parallel to the x-axis. Light ray 1214 reflects off one of the faces 1218 facing the y-direction, and emerges from the substrate 1202 travelling in the y-z plane, with a direction component parallel to the y-axis. Therefore, the structures may be shaped to have reflecting faces oriented to reflect light along both the x- and y-directions.

The angle of the faces in one direction may be different from the angle of the faces
20 in the other direction, to provide different amounts of dispersion in the x- and y- directions. For example, the structures 1104 may be pyramidal in shape, and have different sets of angles for dispersing in the x and y directions. This is illustrated in FIGs. 13A and 13B. Fig. 13A illustrates a cross-section through the dispersing layer 1200 parallel to the x-axis. The three structures 1204 may be provided with three different apex angles θ_{1x} , θ_{2x} , and
25 θ_{3x} , in a manner similar to that described above with regard to FIG. 9 to reduce the effects of the off-center peak and the gain dip. Likewise, the structures may be provided with different apex angles for dispersing the light in the y-direction. FIG. 13B illustrates a cross-section through the dispersing layer 1200 parallel to the y-axis. The structures 1204 may be provided with different apex angles θ_{1y} , θ_{2y} , θ_{3y} , θ_{4y} , and θ_{5y} for reducing the effects of
30 the off-center peak and the gain dip. It will, of course, be appreciated, that the structures

1204 may also be provided with curved reflecting surfaces, or with reflecting surfaces having rectilinear portions, for reducing the effects of the off-center peak and the gain dip.

The structures 1204 in FIG. 12 are positioned so as to provide a clear area 1208 that has a "checkered" pattern, of stripes in the x- and y-directions. The positions of the structures may be different, resulting in a different pattern of clear area. For example, in FIG. 14, the structures 1404 are arranged on the substrate 1402 so that the corners of their bases touch. This results in a pattern of clear areas 1408 that resembles a checkerboard, and may provide an advantage of increasing the contrast of the screen without reducing the net throughput of light from the image light source. It should be appreciated that other spatial arrangements of structures may be used.

It will be appreciated that two dimensional structures, having shapes other than those shown in FIGs. 12 and 14 may be employed. For example, the structures may be formed to have rectangular bases, or bases having some other four sided shape useful. Additionally, the structures may be formed having bases with other numbers of sides, including three, five, six, and so on.

Another embodiment of a light dispersing layer is illustrated in FIG. 15. The dispersing layer 1500 is formed from light absorbing, internally reflecting structures 1504 positioned on a surface of a substrate 1502. The valleys between adjacent structures 1504 are filled with a high refractive index material 1506, and clear areas 1508 lie between the bases 1512 of the structures 1504. The internally reflecting surface 1510 of the structure 1504 may be straight. The coating of high refractive index material 1506 includes layers 1506a, 1506b and 1506c of increasing refractive index, which serve to spread the reflected light out over more than one direction and to focus the light, thus permitting the size of the clear area between adjacent structures 1504 to be reduced, thus increasing the screen contrast.

The first light ray 1514 is reflected from the reflecting surface 1510 within the first high index layer 1506a. The ray 1514 is refracted towards a direction parallel to the screen axis 1520 on passing into the second high index layer 1506b which has a higher refractive index than the first high index layer 1506a. The first light ray 1514 is further refracted towards the screen axis 1520 on passing into the third high index layer 1506c before passing into the substrate 1502.

The second light ray 1516 is reflected from the reflecting surface 1510 within the second high index layer 1506b. The ray 1516 is refracted towards a direction parallel to the screen axis 1520 on passing into the third high index layer 1506c which has a higher refractive index than the second high index layer 1506b. The second ray 1516 then passes
5 into the substrate 1502.

The third light ray 1518 is reflected from the reflecting surface 1510 within the third high index layer 1506c and undergoes no further refraction within the high index layer 1506 before entering the substrate 1502. The third light ray 1518 emerges from the substrate 1502 at a higher angle than the second light ray 1516 since the third light ray was
10 not refracted within the high index layer 1506. Also, the second light ray 1516 emerges from the substrate at a higher angle than the first light ray 1514, since it undergoes fewer refractions than the first ray 1514.

Thus, a layered high index material 1506 may be used to spread the light reflected from a structure 1504 having straight reflecting surfaces, thus reducing the off-axis gain peak and gain dip. The layered high index material may, of course, also be used with
15 reflecting structures having faceted, or curved reflecting surfaces. Furthermore, since the effect of the layered high index material 1506 is to direct light towards the screen axis 1520, the spacing between structure bases 1512 may be reduced, with a concomitant increase in screen contrast.

A layered high index material may be used where the refractive index decreases from top to bottom, rather than increasing from top to bottom. Such a layered high index layer will also have the effect of increasing the angular range of light reflected from a flat reflecting surface. However, such a layer will tend to defocus light, rather than focus the light as it propagated through the layer, and so the reflecting structures may need to be
20 spread further apart to avoid second reflections from adjacent structures, and so the contrast may be reduced.

It should be appreciated that a high index material having a refractive index that is graded from top to bottom operates in a manner similar to the layered high refractive index material. Thus, the layered high index material of the film 1500 may be replaced by a
30 graded high index layer.

Since the present invention is particularly useful for reducing the interdependence of the horizontal and vertical viewing angles, a surface scatterer may be used for dispersing light in the vertical dispersion plane. One example is shown in FIG. 16, which illustrates a film 1600 having a substrate with structures 1604 on an upper substrate surface, separated by clear areas 1608. An overcoat 1606 of high refractive index material covers the structures 1604 and the clear areas 1608. The interface 1614 between the overcoat 1606 and the substrate 1602, at the clear areas 1608 between the structure bases 1612, may be structured to optically scatter the light passing through the clear areas 1608, where there is a refractive index difference between the overcoat 1606 and the substrate. For example, the interface 1614 may be have a random matte surface that scatters light isotropically, or may have a surface that scatters light asymmetrically, such as a microstructured or microholographic interface. One example of a method of forming a surface scatterer is to form a scattering surface on the substrate 1602 prior to formation of the structures 1604. If the structures 1604 are then formed on the substrate 1602 to have a refractive index that closely matches that of the substrate, then index matching will effectively remove the scatterer at the bases of the structures 1604, leaving surface scatterer only at the clear areas 1608 between the structure bases. An advantage of this approach is that ambient light entering the substrate from the viewer's side is not scattered before entering the absorbing bases 1612.

Another example of using a surface scatterer is illustrated in FIG. 17, which shows a film 1700 with low refractive index structures 1704 on a substrate 1702, with an overcoat 1706 of high index material covering the structures 1704 and the clear areas 1708 between the structure bases 1712. The lower surface 1714 of the substrate 1702 may be structured to optically scatter the light that emerges from the substrate 1702. For example, the lower surface 1714 may be have a random matte surface that scatters light isotropically, or may have a surface that scatters light asymmetrically, such as a microstructured or microholographic surface.

One particular example of a microstructured surface being used at the open areas is illustrated in FIG. 22. Here, structures 2204 of light absorbing, low refractive index material are disposed over a substrate 2202. A coating of relatively high refractive index 2206 overlies the structures 2204 and the open areas 2208 between the structures 2204.

Refractive structures 2210 are disposed in the upper portion of the substrate 2202, at the open areas 2208, to refract the light passing through the open areas. The refractive structures 2210 may be, for example, lenticular lenses embedded in the substrate. The refractive structures 2210 may also be shaped as lenslets that diverge light in more than one dispersion plane. A lenslet refractive structure 2210 may be used, for example, to disperse light in a horizontal dispersion plane, in the same direction as the reflective dispersion resulting from the structures 2204, as well as to disperse light in a vertical dispersion plane.

Another embodiment of a light dispersing layer 1800 is illustrated in FIG. 18, in which the shape of the internally reflecting structures changes as a function of distance from the center of the screen. Here, a source 1820 directs image light towards a light dispersing layer 1800 having number of structures 1804 of low refractive index material embedded within a layer 1806 of high refractive index material. The structures 1804 may also include light absorbing material to provide contrast to the screen.

The structures 1804 may be shaped to reduce the divergence of light emerging from the screen. The structures 1804 may be formed as ribs, as off-set pyramids, or may also be formed in a radially symmetrical design, as rings around the center of the screen.

The difference in refractive index between the structures 1804 and the high index layer 1806 is selected so that light incident on the structures 1804 undergoes total internal reflection, and is consequently directed through the open spaces 1808 between the structures 1804. In one embodiment, described with reference to FIG. 19, the structures are set with the leading edge 1804a at an angle, θ_L , of 5° . The trailing edge 1804b may be set to be parallel to the ray just clearing the top of the structure 1804 on the way through the high index layer 1806. At this angle, no light is internally reflected in a direction away from the center of the screen, and so the overall divergence of light from the screen is reduced.

The spacing between structures 1804 is preferably smaller than a screen pixel size in order to maintain high screen resolution. Minimizing the total area of the open space 1808 increases screen contrast, because more light absorbing area is presented to the viewing side of the screen. However, if the structures 1804 are set too closely together, then light reflected off the leading edge 1804a of one structure 1804 may be reflected into the trailing

edge 1804b of the adjacent structure 1804, resulting in a loss of light. Accordingly, there is a trade-off between screen transmission and screen contrast.

Another method of manufacturing a film of the present invention is described with reference to FIGs. 20A - 20C. First, a grooved film 2000, as illustrated in FIG. 20A, is formed from a material having a relative high refractive index. The film 2000 may be formed using a cast and cure process. Curing may be thermal or optical. The grooves 2002 on the lower side of the film 2000 are separated by flat surfaces 2004, also known as land.

The flat surfaces 2002 are coated with a layer of diffuser 2006, which may be a bulk diffuser similar to that described above, to produce the unfinished article illustrated in FIG. 20B. The diffuser 2006 may be coated onto the flat surfaces 2002 using a printing process, for example lithographic or letter press or off-set printing.

Once the diffuser 2006 has been applied, the grooves 2002 are filled, typically in a planarization process, with a material of a relatively low refractive index to form low index structures 2008, as shown in FIG. 20C. A thin layer 2010 of the low index material, loaded with absorbing material, may be left at the flat surfaces 2004 to create a thin land of low index material.

A method for manufacturing another embodiment of a reflectively dispersing screen film is illustrated in FIG. 23. The first step is to form a number of structures 2304 on a substrate 2302, for example using a cast and cure process as described above, to produce the film shown at Step 1. Next, an overcoating of a removable material is laid over the structures 2304 and the substrate 2302. The removable material may be a polymer, such as a photoresist or another polymer that is removable in a controlled manner, for example using a wet etchback, laser ablation, or a dry etch. Examples of additional etchback processes for removing a polymer are discussed in U.S. Patent Application Serial No. 08/999,287, which is incorporated herein reference. The removable material may then be removed in a controlled manner to leave only portions 2310 at the bottom of the valleys between adjacent structures 2304, covering the clear areas 2308, as shown at Step 2&3.

A metal coating 2312 may then be disposed over the film 2300, for example by vacuum coating. The metal may be aluminum, or any other metal with suitable reflection characteristics for the particular application. The resulting film is shown at Step 4.

The remaining removable material 2310 may then be removed, for example in a lift-off process. For example, if the removable material is a photoresist, then the remaining photoresist portions may be removed in a sodium hydroxide bath or spray. For other types of removable material, the remaining portions 2310 may be removed using a suitable solvent. An overcoat layer 2334 may then be disposed over the metalized structures 2304 and the open areas 2308, for example using a planarization process. The resulting film 2330 is illustrated at Step 5, with metalized portions 2332 coated on the structures 2304.

Metalized coatings, such as illustrated in FIG. 23, may be used with any of the other embodiments discussed above, where applicable, and also with different combinations of embodiments.

While various examples were provided above, the present invention is not limited to the specifics of the illustrated embodiments. For example, while many embodiments were described with a substrate layer, the internally reflecting structures may be embedded within the high refractive index layer, without a substrate layer. On the other hand, the internally reflecting, light dispersing layer may be but one of a number of layers used in a rear projection screen. Furthermore, it will be appreciated that light may undergo more than one internal reflection on passing through the film, for example light may be reflected off a first structure to a second structure, and may reflect off the second structure before passing through the clear area between structures. Where the refractive index difference between the structures and the high index layer is sufficiently high, the second reflection may be a total internal reflection. Furthermore, internal reflection may take place at the interface between the high index material and the structure at angles less than the critical angle, particularly where light has been diffusely scattered before reaching the interface. In such a case, a large fraction of the light may still be reflected, even though total internal reflection does not take place.

It will be appreciated that the structures present in a film need not all be formed to have the same height. It will also be appreciated that the outer surfaces of the light dispersing layer and/or the screen may be treated with additional coatings for protection against physical damage, such as hard coatings and anti-smudge coatings. In addition, antireflection coatings may be provided on the outer surfaces to reduce reflective losses.

It will further be appreciated that reflectively dispersing screen films may be formed that include various combinations of the approaches presented above. For example, an internally reflecting screen may be formed using faceted structures with different inter-structure spacings between different adjacent structure pairs. Also, a metalized coating
5 may be formed on a structure having a curved reflecting surface.

As noted above, the present invention is applicable to display systems as a light dispersing film. It is believed to be particularly useful in back projection displays and screens. Accordingly, the present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects
10 of the invention as fairly set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art to which the present invention is directed upon review of the present specification. The claims are intended to cover such
15 modifications and devices.

WE CLAIM:

1. A light dispersing film for a rear projection screen, comprising:

a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and an optical axis normal to the first side,

the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with one or more side walls extending towards the first side, first internal reflecting surfaces being formed by interfaces between the first and second materials, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases,

the first internally reflecting surfaces forming reflecting units that asymmetrically disperse light through respective optically transmitting areas, the first reflecting surfaces forming surfaces disposed at at least two angles relative to the optical axis.

2. A film as recited in claim 1, wherein at least a portion of one of the first internally reflecting surfaces is curved.

3. A film as recited in claim 2, wherein the curved portion of the one of the first internally reflecting surfaces is paraboloidal.

4. A film as recited in claim 1, wherein at least one of the first internally reflecting surfaces includes two or more rectilinear portions disposed at different angles relative to the optical axis.

5. A film as recited in claim 1, wherein a first separation distance between a first pair of adjacent structures is different from a second separation distance between a second pair of adjacent structures.

6. A film as recited in claim 1, wherein an inclusion angle is defined for each of the structures, different structures having different inclusion angles.

7. A film as recited in claim 1, wherein the first internally reflecting surfaces are arranged to reflect light propagating in a direction approximately parallel to the optical axis within the first layer, the reflected light propagating in directions substantially parallel to a first dispersion plane, and the structures have second internally reflecting surfaces oriented to reflect light, propagating in a direction approximately parallel to the optical axis within the first layer, in directions parallel to a second dispersion plane perpendicular to the first dispersion plane.

8. A film as recited in claim 1, wherein the second material is a light absorbing material.

9. A film as recited in claim 1, wherein the structures are formed in the first layer as parallel members extending over substantially an entire width of the first layer.

10. A film as recited in claim 1, wherein the first layer includes diffusing portions positioned proximate the optically transmitting areas of the second side.

11. A film as recited in claim 10, wherein the diffusing portions include a scattering surface on the second side to scatter light propagating through the optically transmitting areas.

12. A film as recited in claim 10, wherein the diffusing portions include a bulk diffusing portion extending from the second side at least part way into the first layer.

13. A film as recited in claim 1, wherein light diffusing particles are disposed throughout the first material.

14. A film as recited in claim 1, further comprising a substrate layer attached to the second side of the first layer.

15. A film as recited in claim 1, wherein the first internally reflecting surfaces are arranged to reflect light, propagating in a direction approximately parallel to the optical axis within the first layer, in directions substantially parallel to a first dispersion plane, and at least one of the surfaces of the substrate layer is structured to disperse light in at least a direction parallel to a second dispersion plane perpendicular to the first dispersion plane.

16. A film as recited in claim 1, further comprising a Fresnel lens disposed to reduce divergence of light entering the first side of the first layer.

17. A film as recited in claim 1, further comprising an image light source disposed to illuminate the first side of the first layer with image light.

18. A film as recited in claim 17, wherein different structures are arranged with structure apexes directed towards the image light source

19. A film as recited in claim 1, wherein structures disposed close to the edge of the first layer are arranged with structure apexes directed away from the edge of the screen.

20. A film as recited in claim 1, wherein at least one reflecting unit includes reflecting surfaces disposed to reflect light, incident on one of the reflecting surfaces of the at least one reflecting unit in a direction substantially parallel to the first optical axis, more than once before the light passes through the optically transmitting area of the at least one reflecting unit.

21. A light dispersing film for a rear projection screen, comprising:

a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side,

the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with one or more side walls extending towards the first side to define first reflecting surfaces, the structure bases including a light absorbing

material, optically transmitting areas of the second side being defined between the structure bases,

the first reflecting surfaces forming reflecting units that asymmetrically disperse light through respective optically transmitting areas, and the first reflecting surfaces being disposed to reflect light to selected directions within a dispersion plane.

22. A film as recited in claim 21, wherein at least a portion of one of the first reflecting surfaces is curved.

23. A film as recited in claim 22, wherein the curved portion of the one of the first reflecting surfaces is paraboloidal.

24. A film as recited in claim 21, wherein at least one of the first reflecting surfaces includes two or more rectilinear portions disposed at different angles relative to the optical axis.

25. A film as recited in claim 21, wherein a first separation distance between a first pair of adjacent structures is different from a second separation distance between a second pair of adjacent structures.

26. A film as recited in claim 21, wherein an inclusion angle is defined for each of the structures, different structures having different inclusion angles.

27. A film as recited in claim 21, wherein the first reflecting surfaces are arranged to internally reflect light propagating in a direction approximately parallel to the optical axis within the first layer, the reflected light propagating in directions substantially parallel to a first dispersion plane.

28. A film as recited in claim 27, wherein the structures have second reflecting surfaces oriented to reflect light, propagating in a direction approximately parallel to the

optical axis within the first layer, in directions parallel to a second dispersion plane perpendicular to the first dispersion plane.

29. A film as recited in claim 21, wherein the second material is a light absorbing material.

5 30. A film as recited in claim 21, wherein the structures are formed in the first layer as parallel members extending over substantially an entire width of the first layer.

31. A film as recited in claim 21, wherein the first layer includes diffusing portions positioned at the optically transmitting areas of the second side.

10 32. A film as recited in claim 31, wherein the diffusing portions include a scattering surface on the second side to scatter light propagating through the optically transmitting areas.

33. A film as recited in claim 31, wherein the diffusing portions include a bulk diffusing portion extending from the second side at least part way into the first layer.

15 34. A film as recited in claim 31, wherein light diffusing particles are disposed throughout the first material.

35. A film as recited in claim 21, further comprising a substrate layer attached to the second side of the first layer.

20 36. A film as recited in claim 35, wherein the first reflecting surfaces are arranged to reflect light, propagating in a direction approximately parallel to the optical axis within the first layer, in directions substantially parallel to a first dispersion plane, and at least one of the surfaces of the substrate layer is structured to disperse light in at least a direction parallel to a second dispersion plane perpendicular to the first dispersion plane.

37. A film as recited in claim 21, further comprising a Fresnel lens disposed to reduce divergence of light entering the first side of the first layer.

38. A film as recited in claim 21, further comprising an image light source disposed to illuminate the first side of the first layer with image light.

39. A film as recited in claim 21, wherein different structures are arranged with structure apexes directed in different directions.

5 40. A light dispersing film for a rear projection screen, comprising:

a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side,

10 the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with one or more side walls extending towards the first side to define first reflecting surfaces, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases,

15 the first reflecting surfaces forming surfaces disposed at two or more angles relative to the optical axis, and

wherein all light reflected by the first reflecting surfaces is reflected at dielectric-dielectric interfaces.

20 41. A film as recited in claim 40, wherein at least one of the first reflecting surfaces is curved.

42. A film as recited in claim 40, wherein at least one of the first reflecting surfaces includes two or more rectilinear portions disposed at different angles relative to the optical axis.

25 43. A film as recited in claim 40, wherein a first separation distance between a first pair of adjacent structures is different from a second separation distance between a second pair of adjacent structures.

44. A film as recited in claim 40, wherein an inclusion angle is defined for each of the structures, different structures having different inclusion angles.

45. A film as recited in claim 40, wherein the second material is a light absorbing material.

5 46. A film as recited in claim 40, wherein the structures are formed in the first layer as parallel members extending over substantially an entire width of the first layer.

47. A film as recited in claim 40, wherein the first layer includes diffusing portions positioned proximate the optically transmitting areas of the second side.

10 48. A film as recited in claim 47, wherein the diffusing portions include a scattering surface on the second side to scatter light propagating through the optically transmitting areas.

49. A film as recited in claim 47, wherein the diffusing portions include a bulk diffusing portion extending from the second side at least part way into the first layer.

15 50. A film as recited in claim 40, wherein light diffusing particles are disposed throughout the first material.

51. A film as recited in claim 40, further comprising a substrate layer attached to the second side of the first layer.

20 52. A film as recited in claim 40, wherein the first reflecting surfaces are arranged to reflect light, propagating in a direction approximately parallel to the optical axis within the first layer, in directions substantially parallel to a first dispersion plane, and at least one of the surfaces of the substrate layer is structured to disperse light in at least a direction parallel to a second dispersion plane perpendicular to the first dispersion plane.

53. A film for a rear projection screen, comprising:
a substrate layer, having a first substrate layer side;

structures, formed from a first material having a first refractive index, having structure bases disposed on the first substrate layer side, sidewalls of the structures extending in directions away from the substrate, structure bases being formed of light absorbing material, and clear areas being defined on the first substrate layer side between the structure bases; and

an overlayer, formed from a second material having a second refractive index larger than the first refractive index, disposed over the structures and the clear areas of the first substrate layer side, interfaces between the overlayer and the sidewalls forming internally reflecting surfaces for light propagating within the overlayer towards the substrate in a direction substantially perpendicular to the substrate.

54. A film as recited in claim 53, wherein the reflecting surfaces form reflecting units that asymmetrically disperse light through respective clear areas on the first substrate layer side.

55. A film as recited in claim 53, wherein the reflecting surfaces are disposed to reduce non-uniformity of light dispersion.

56. A film as recited in claim 53, wherein the internally reflecting surfaces are disposed at two or more angles relative to an optical axis of the film.

57. A light dispersing film for a rear projection screen, comprising:

a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side,

the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with one or more side walls extending towards the first side to define first reflecting surfaces, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases; and

a bulk diffuser disposed to disperse light passing through the optically transmitting areas of the second side.

58. A film as recited in claim 57, wherein the bulk diffuser includes light diffusing particles in the first layer proximate the optically transmitting areas.

5 59. A film as recited in claim 57, wherein the bulk diffuser includes light diffusing particles disposed throughout the first material.

60. A method of manufacturing an optical film, comprising:
casting and curing structures on a substrate, the structures being formed from a first material having a first refractive index and with optically absorbing bases on the substrate, open substrate areas being defined between adjacent structures on the substrate;

10 overcoating the structures and the open substrate areas with a second material having a second refractive index greater than the first refractive index, so as to form reflecting surfaces at interfaces between the first and second materials, the reflecting surfaces disposed to reflect light, propagating through second material substrate in a direction substantially parallel to an optical axis of the film, towards open substrate areas.

61. A method of forming an optical film, comprising:
forming grooves on a first side of a film of first material having a first refractive index, with open areas of the first side between the grooves;
forming an optical scatterer on the open areas of the first side;
filling the grooves with a second material having a second refractive index smaller than the first refractive index, the second material being optically absorbing.

62. A light dispersing film for a rear projection screen, comprising:
25 a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side,

the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with at least two side walls extending towards the first side, internal reflecting surfaces being formed by interfaces between the first and second materials, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases,

at least one structure having at least one of the two sidewalls disposed at an angle selected to be parallel to diverging light passing through the film from an image light source positioned on the first optical axis.

63. A light dispersing film for a rear projection screen, comprising:

a first film first and second opposing sides, and having a first refractive index within a first refractive index range,

the first film including structures formed from a structure material having a second refractive index less than the first refractive index range, the structures having bases at the second side with one or more side walls extending towards the first side, first internal reflecting surfaces being formed by interfaces between the structure material and material of the first film, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases,

the first refractive index of the first film proximate the first side being different from the first refractive index of the first film proximate the second side.

64. A light dispersing film for a rear projection screen, comprising:

a first layer formed from a first material having a first refractive index, the first layer having first and second opposing sides and a first optical axis normal to the first side,

the first layer including structures formed from a second material having a second refractive index smaller than the first refractive index, the structures having bases at the second side with one or more side walls extending towards the first side, metal coatings being disposed on at least portions of the sidewalls between the

first and second materials to form first reflecting surfaces, the structure bases including a light absorbing material, optically transmitting areas of the second side being defined between the structure bases,

the first reflecting surfaces forming reflecting units that asymmetrically
5 disperse light through respective optically transmitting areas, and
a bulk diffuser being disposed within the first material to disperse light passing through the optically transmitting areas of the second side.

65. A film as recited in claim 64, wherein the bulk diffuser includes light diffusing particles in the first layer proximate the optically transmitting areas.

10 66. A film as recited in claim 64, wherein the bulk diffuser includes light diffusing particles disposed throughout the first material.

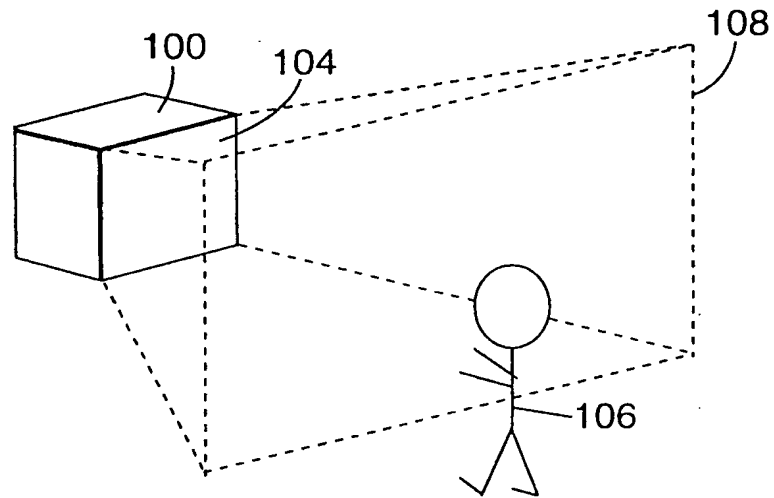
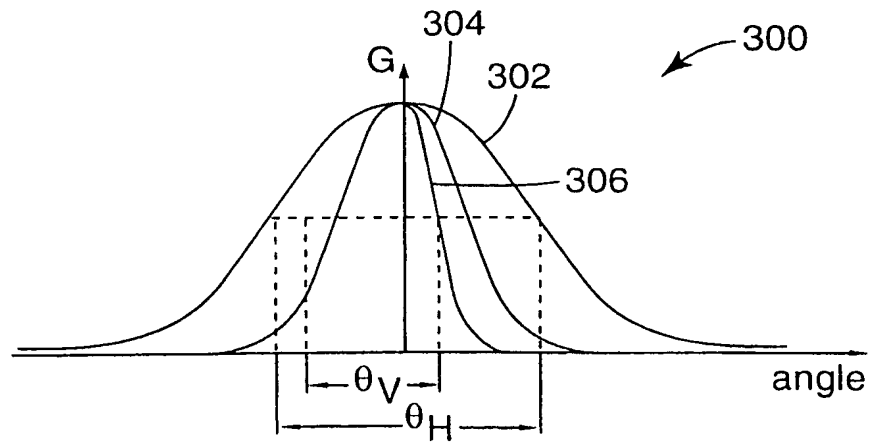
67. A method of forming an optical film, comprising:

casting and curing structures on a substrate, the structures being formed from a first material and with optically absorbing bases on the substrate, open
15 substrate areas being defined between adjacent structures on the substrate;

disposing a metallic layer over at least part of the structures to form reflecting surfaces, the reflecting surfaces being disposed to reflect light, propagating through second material substrate in a direction substantially parallel to an optical axis of the film, towards open substrate areas; and

20 overcoating the metallic layer and the open substrate areas with a second material.

1/16

**Fig. 1****Fig. 3**

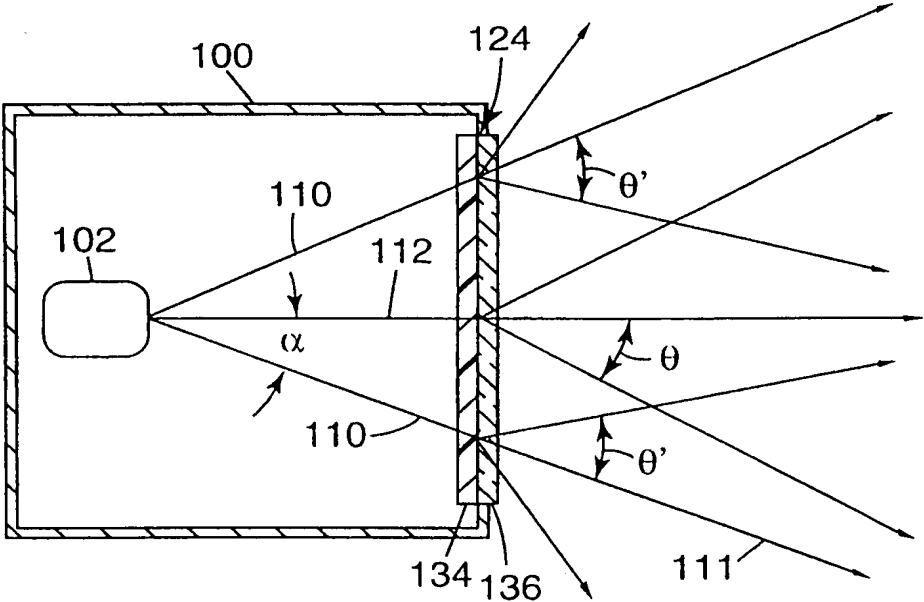


Fig. 2A

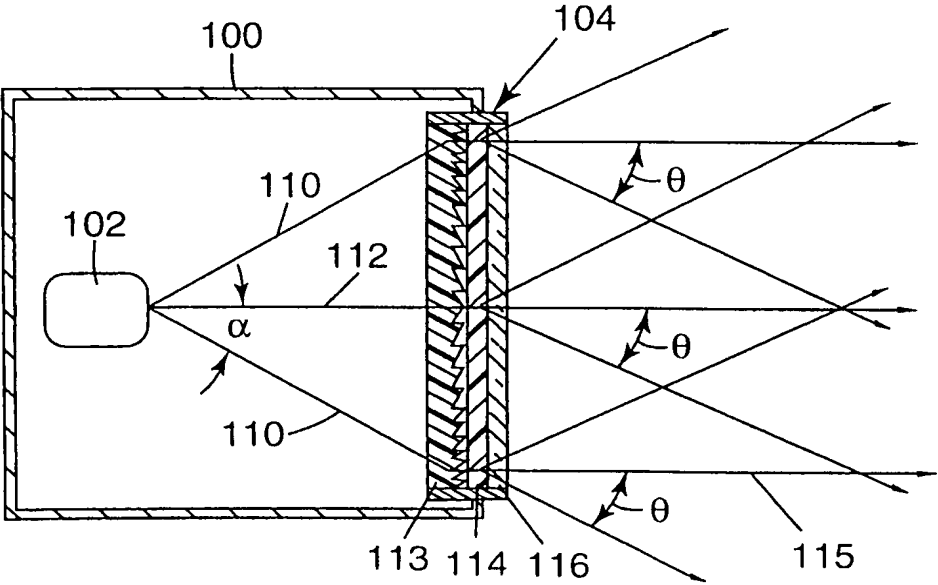
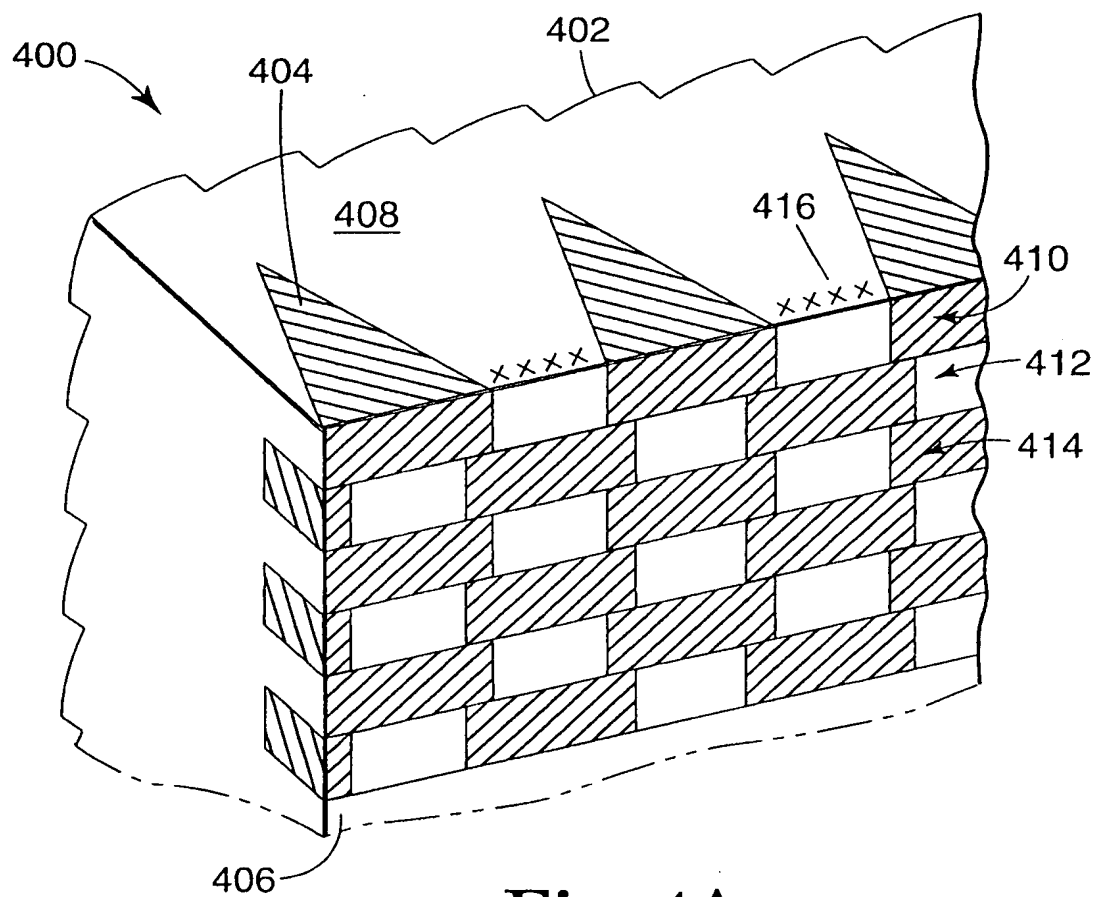


Fig. 2B

3/16

**Fig. 4A**

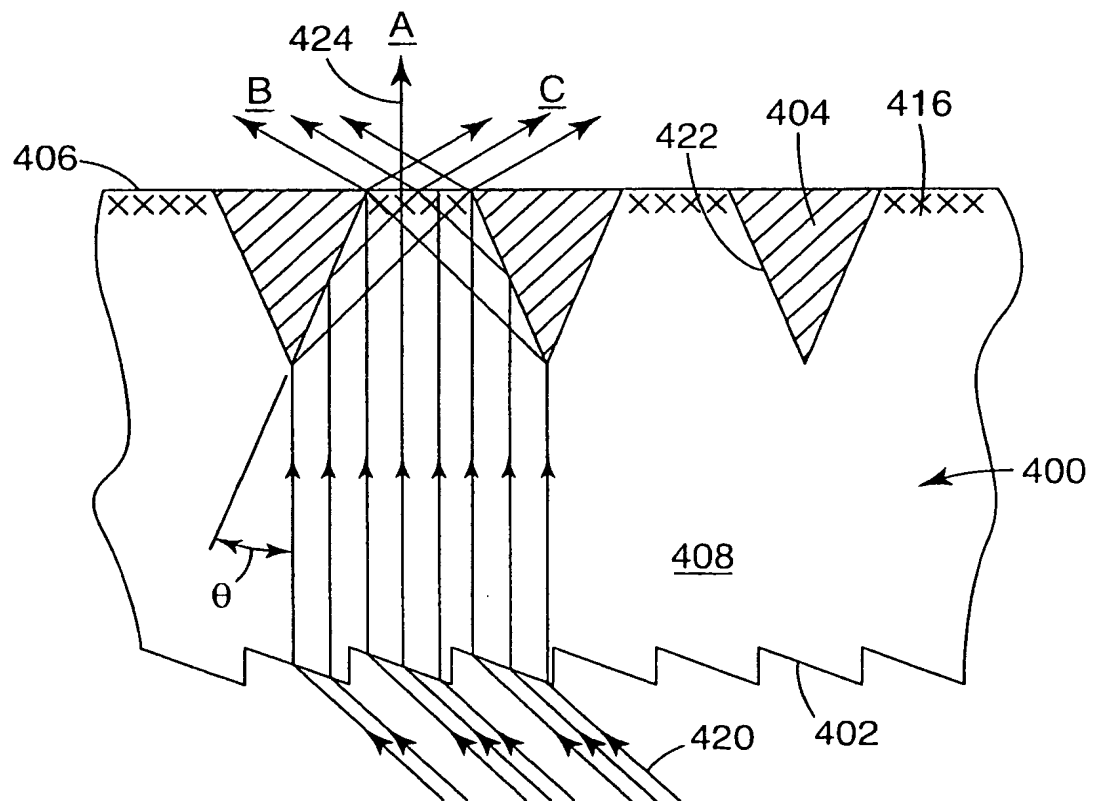


Fig. 4B

5/16

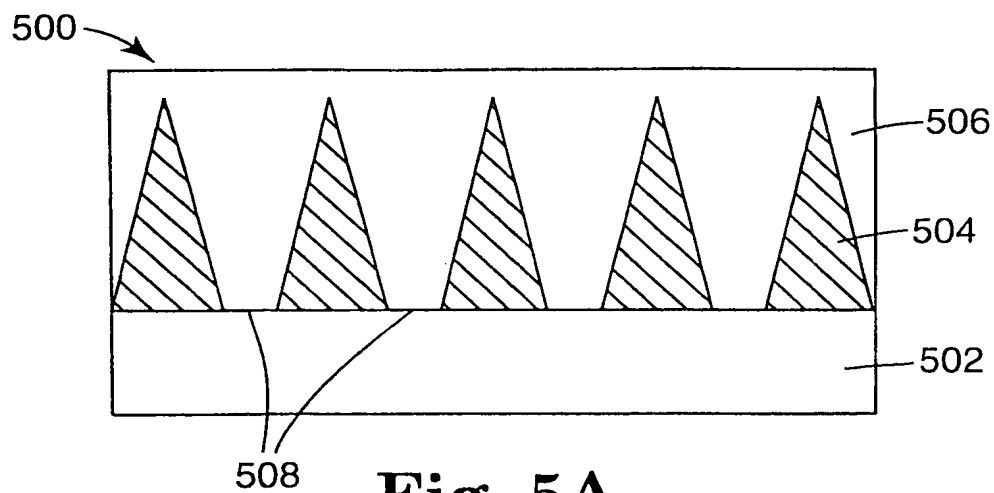


Fig. 5A

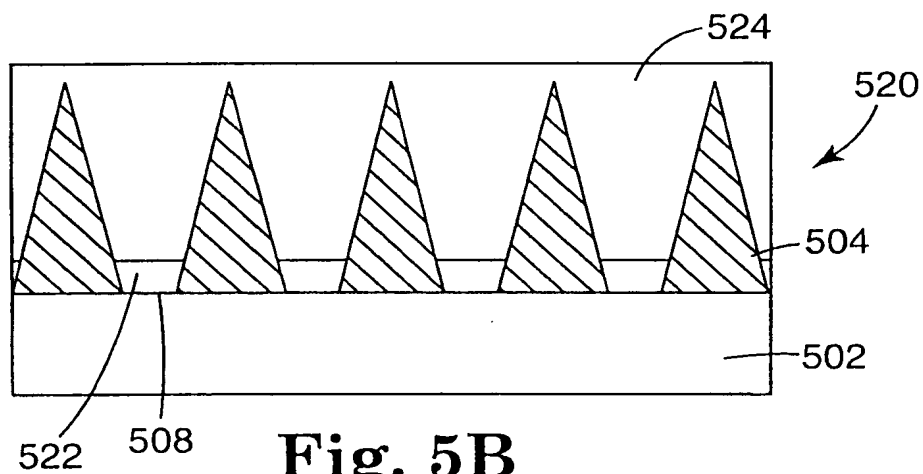


Fig. 5B

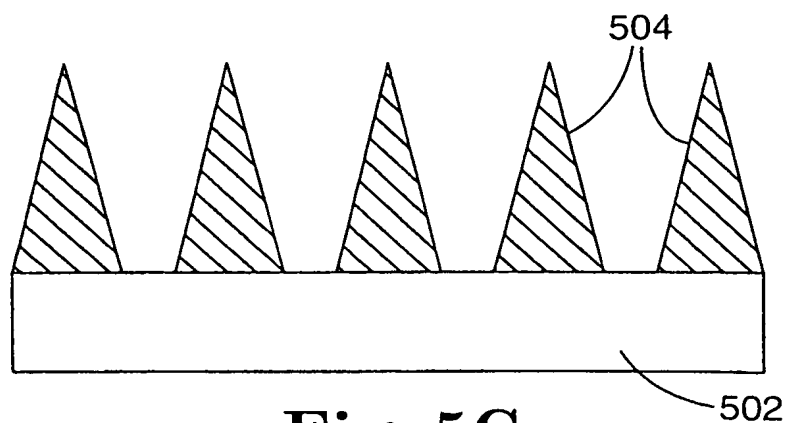
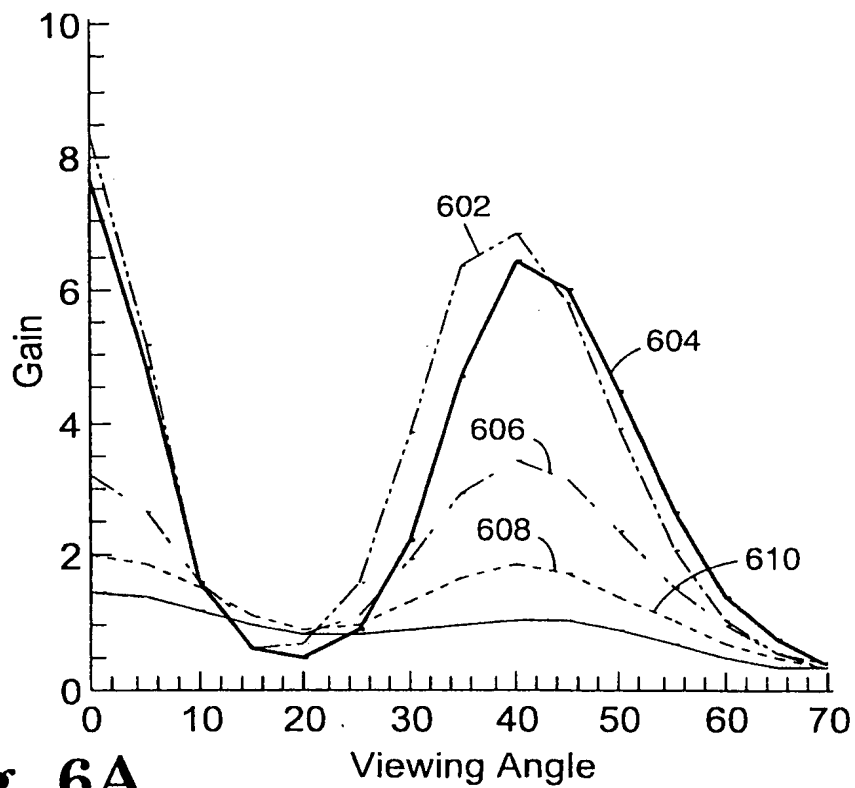
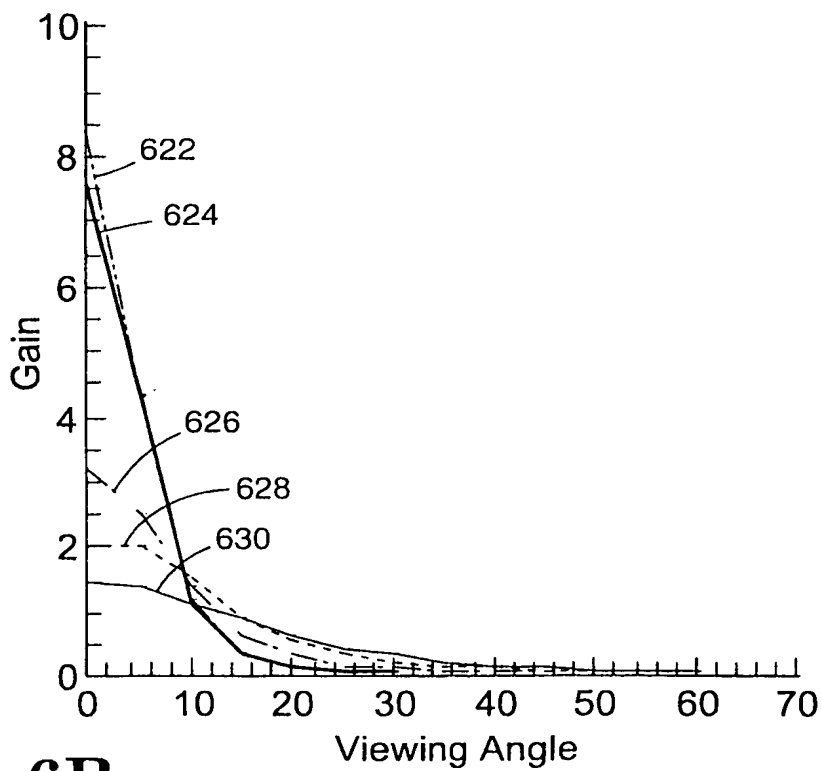


Fig. 5C

6/16

**Fig. 6A****Fig. 6B**

7/16

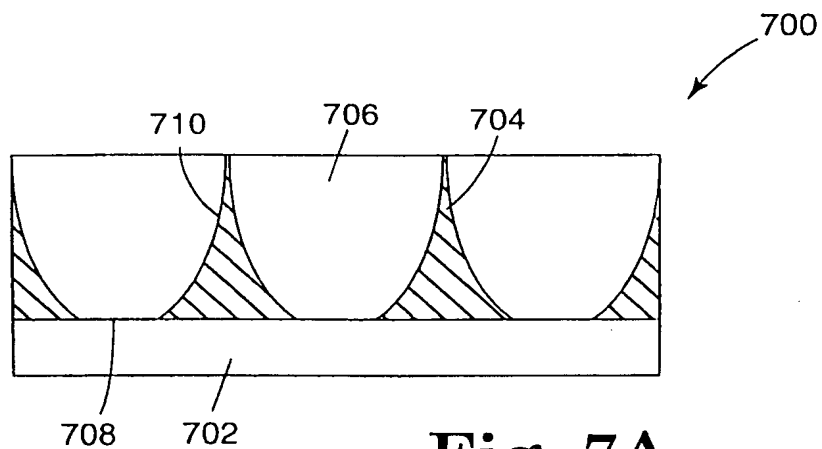


Fig. 7A

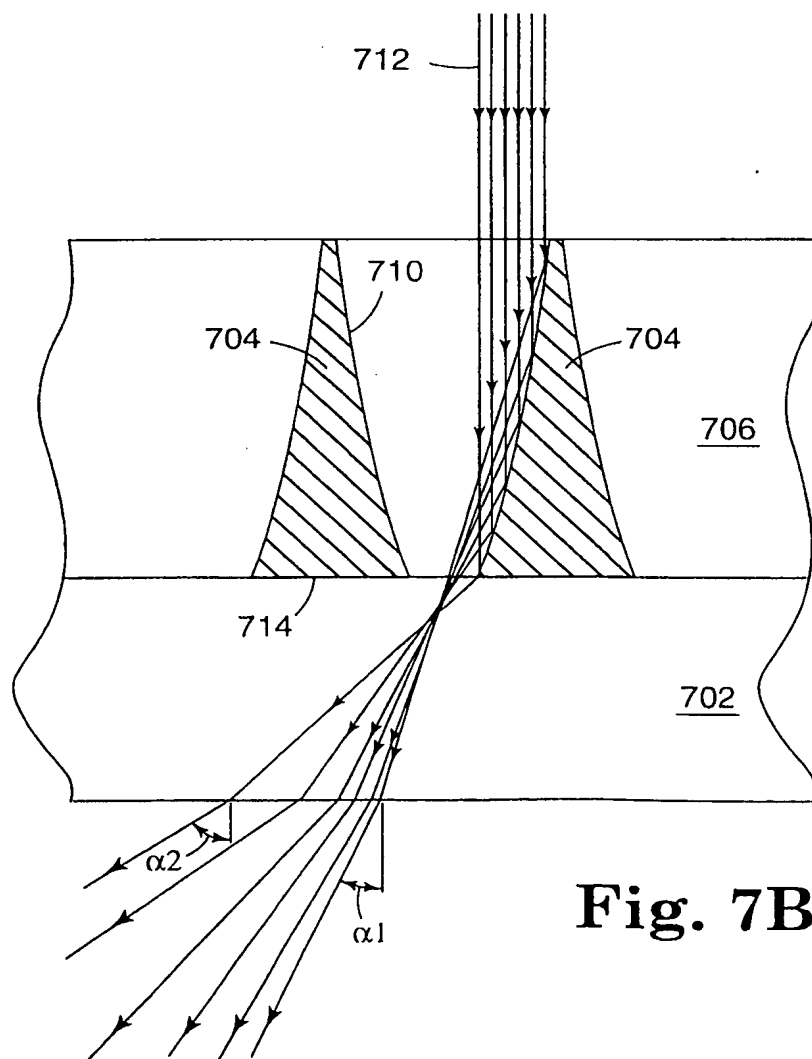


Fig. 7B

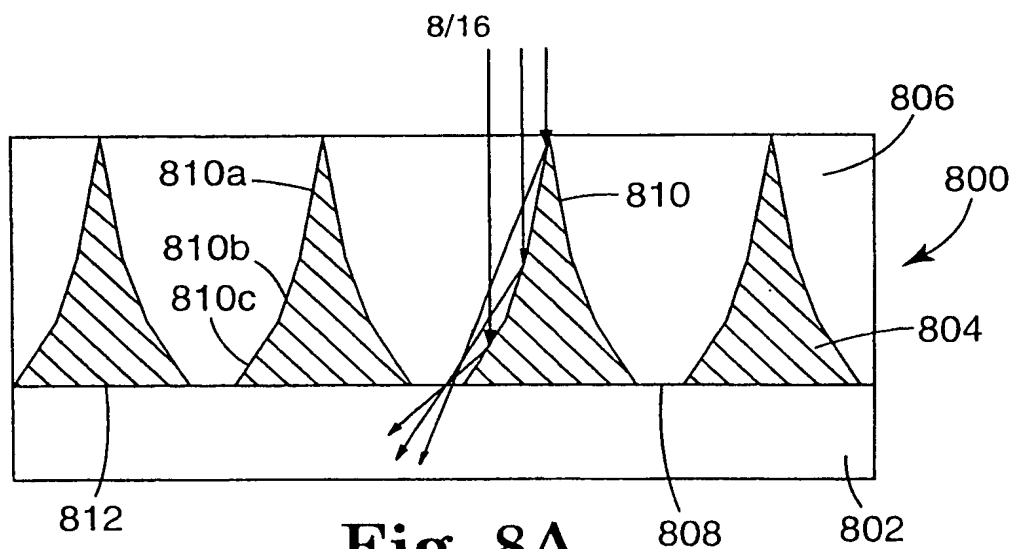


Fig. 8A

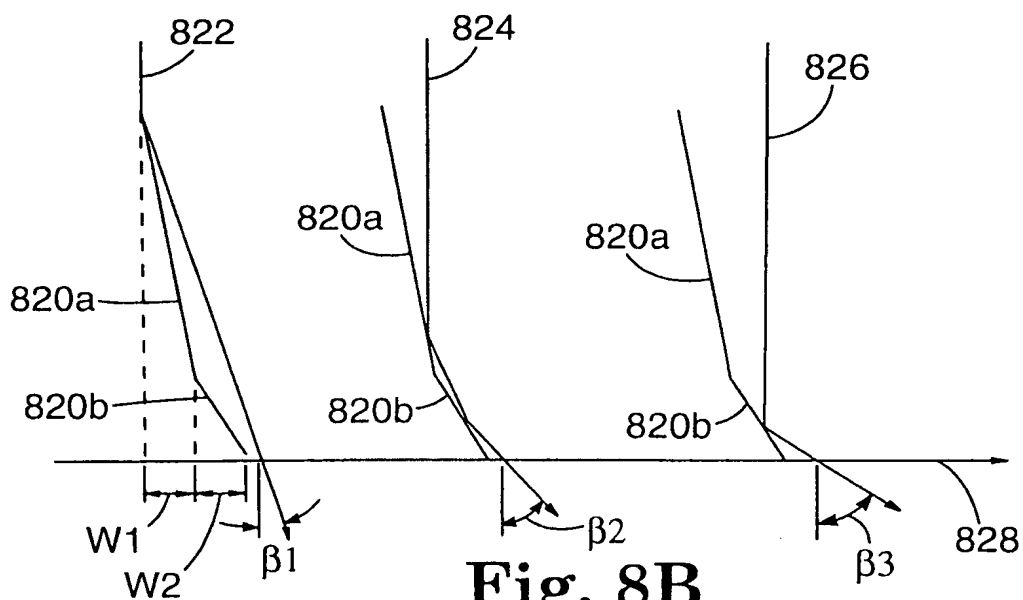


Fig. 8B

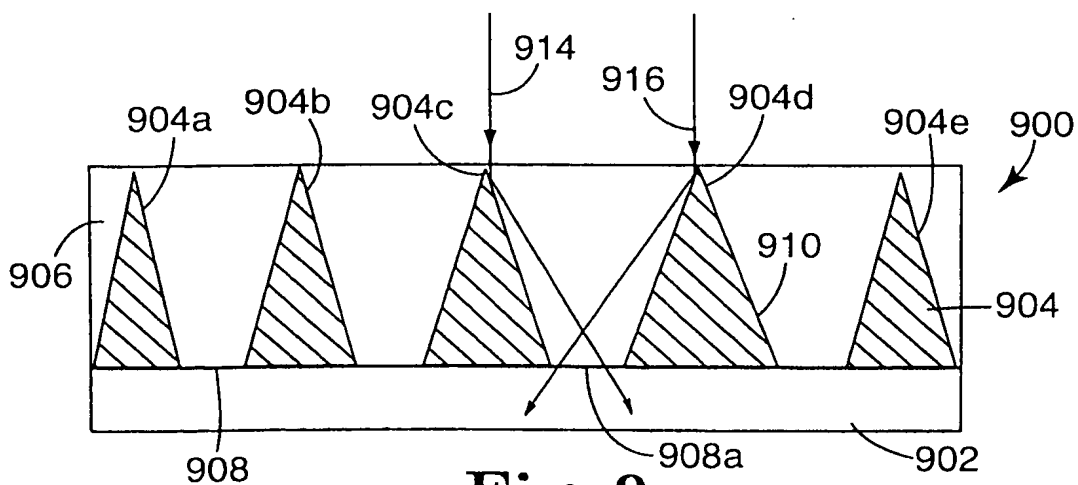
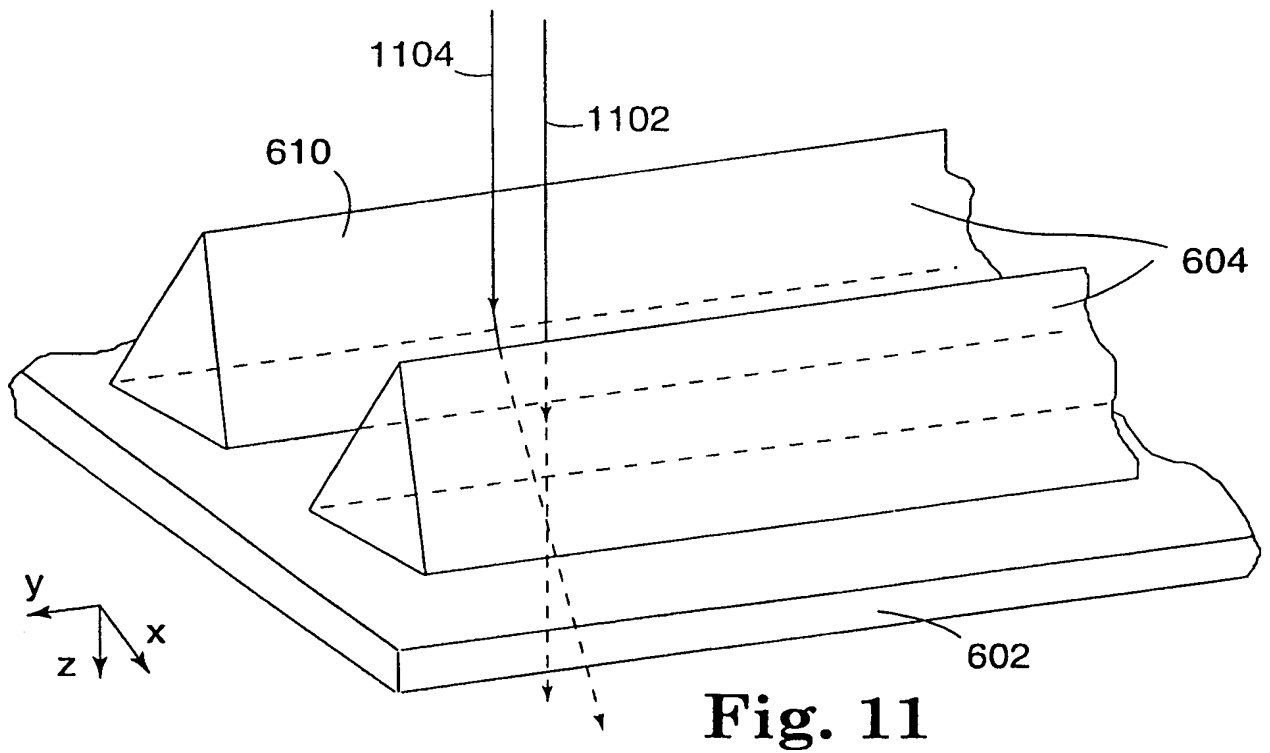
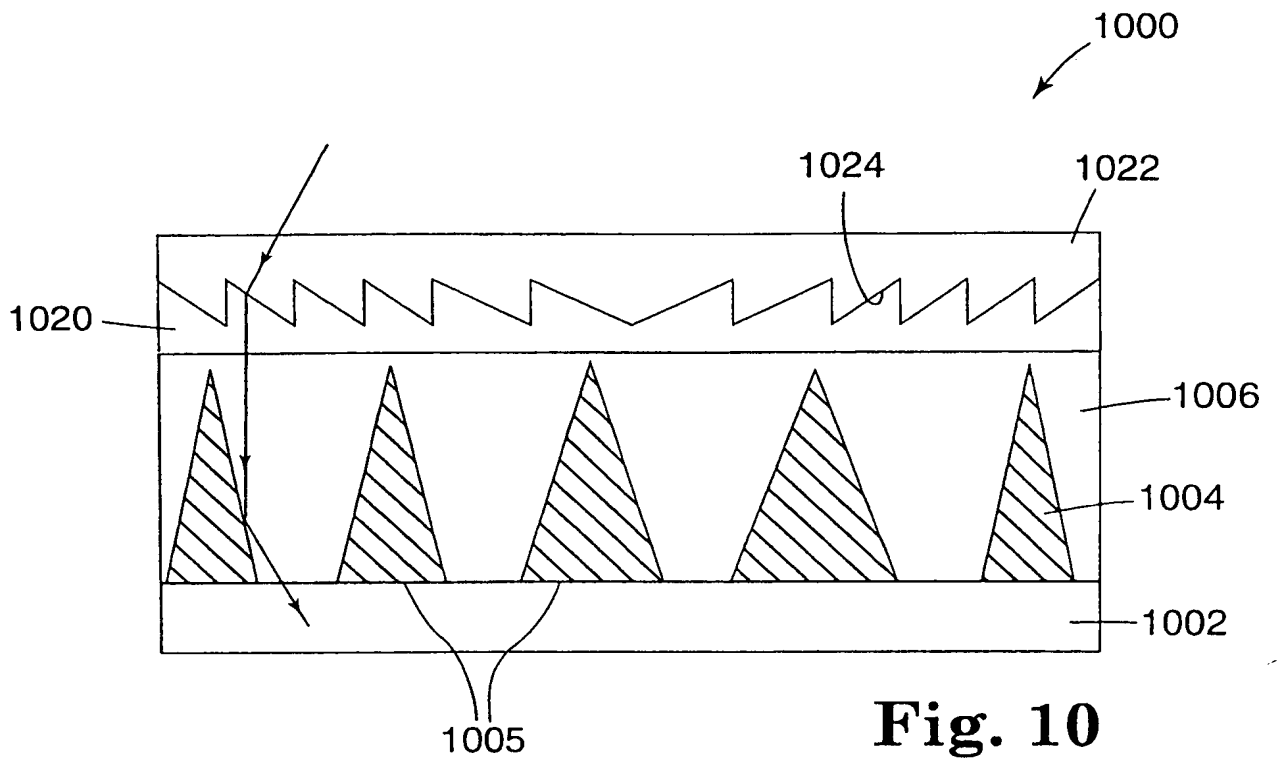


Fig. 9

9/16



10/16

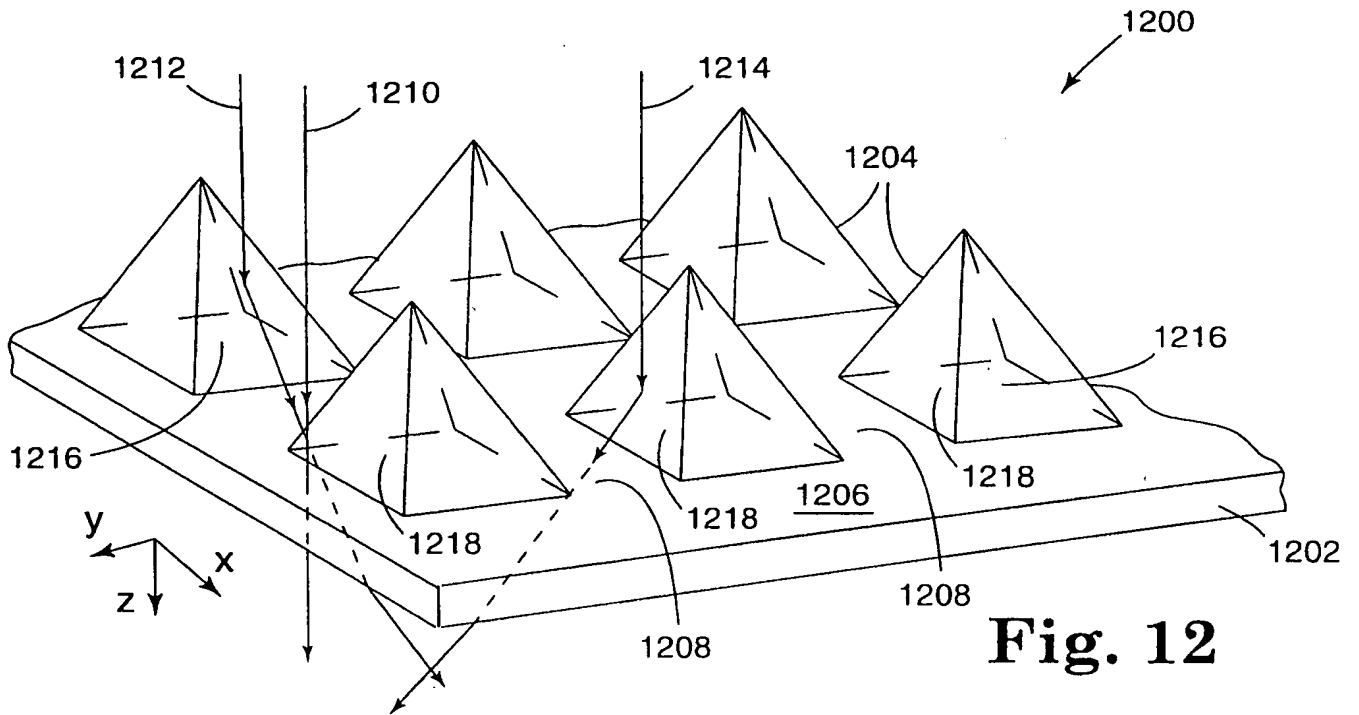


Fig. 12

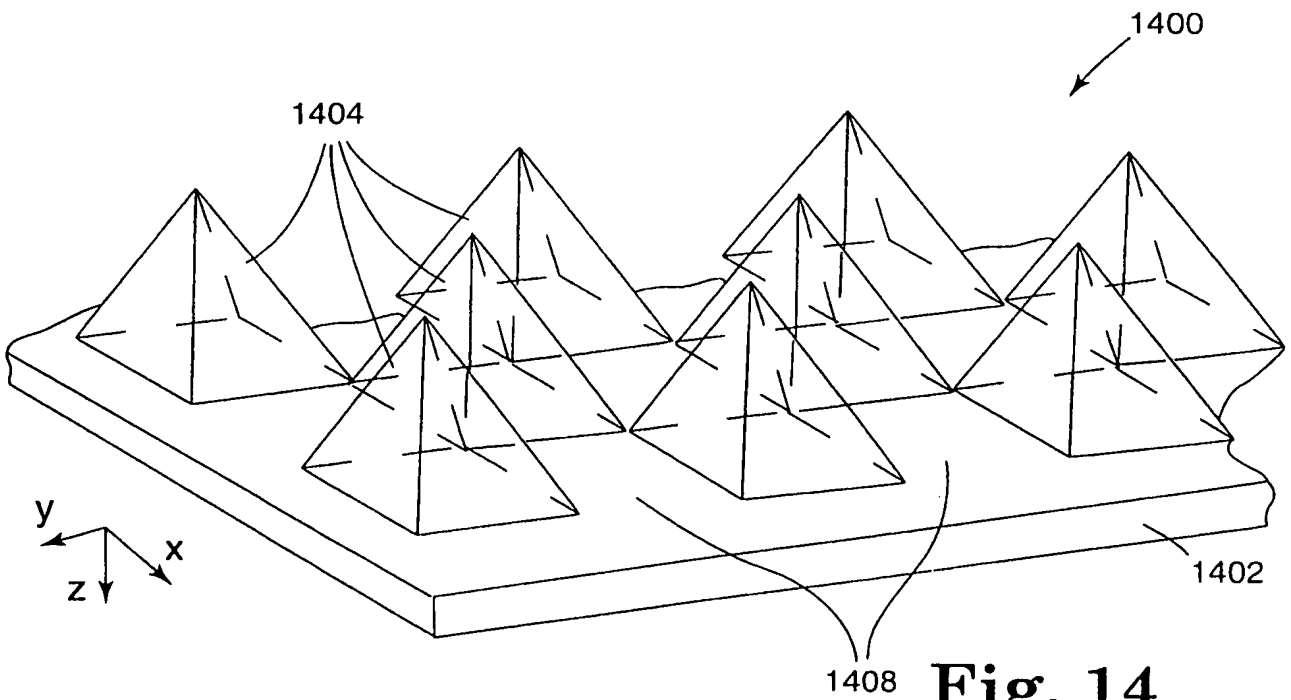
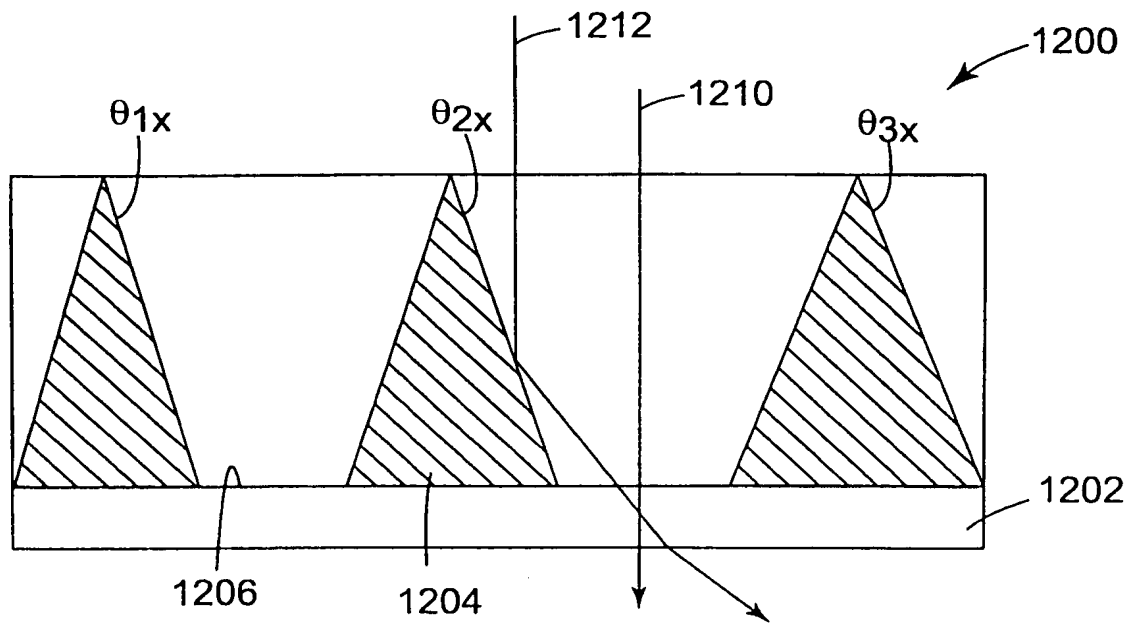
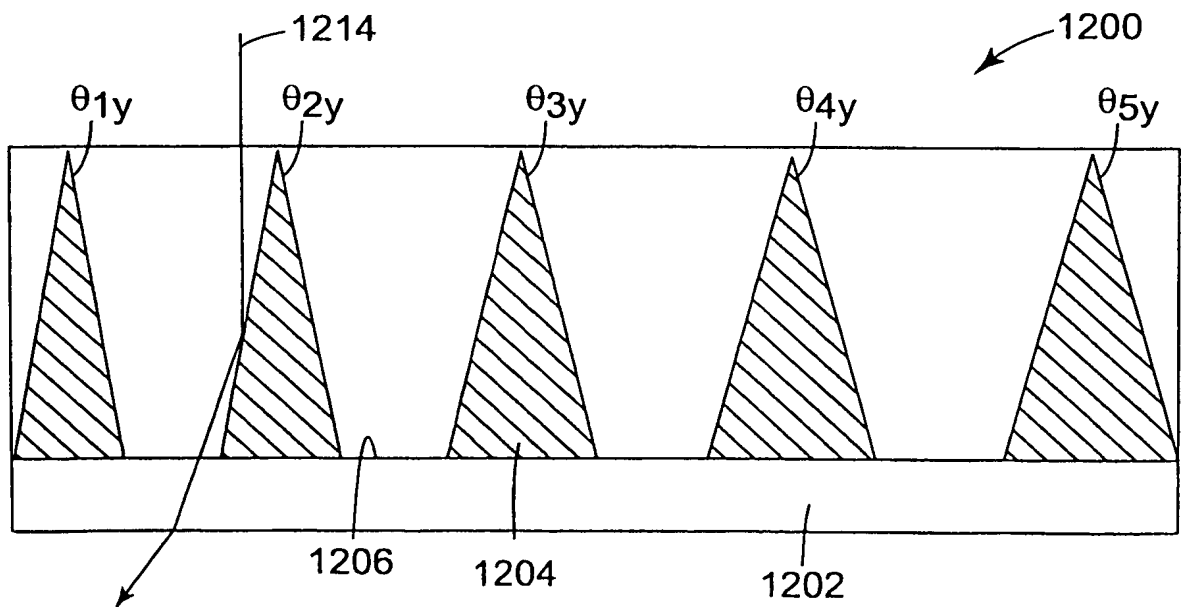


Fig. 14

11/16

**Fig. 13A****Fig. 13B**

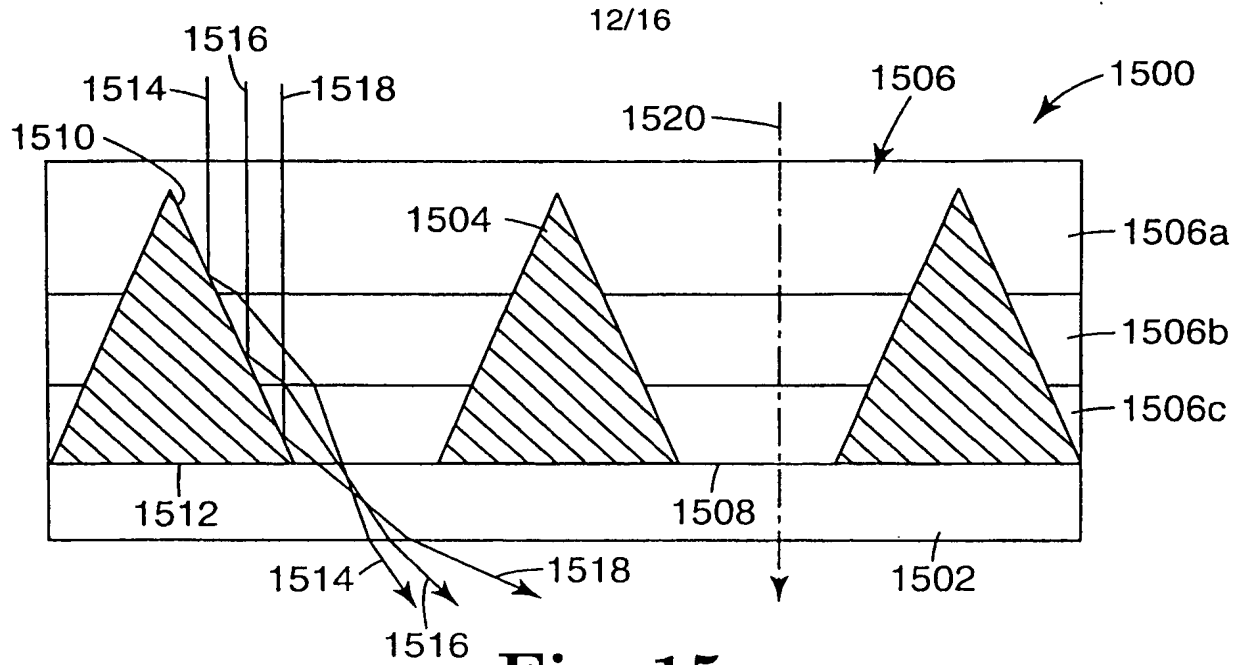


Fig. 15

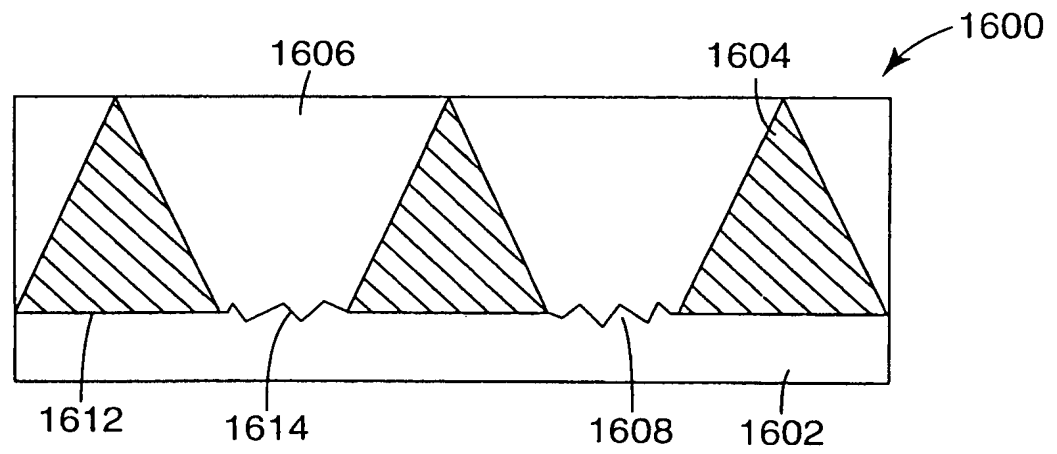


Fig. 16

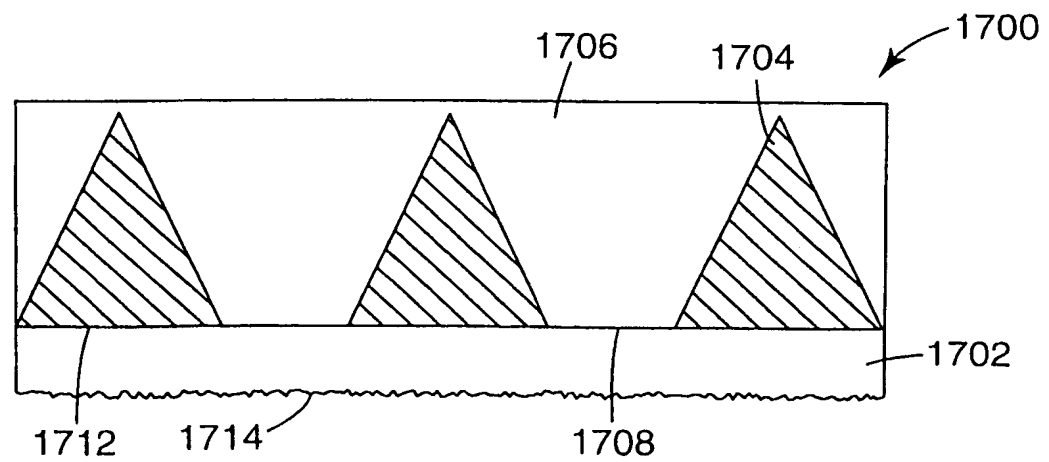
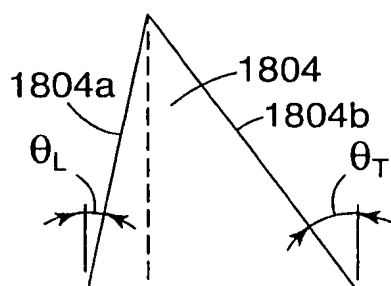
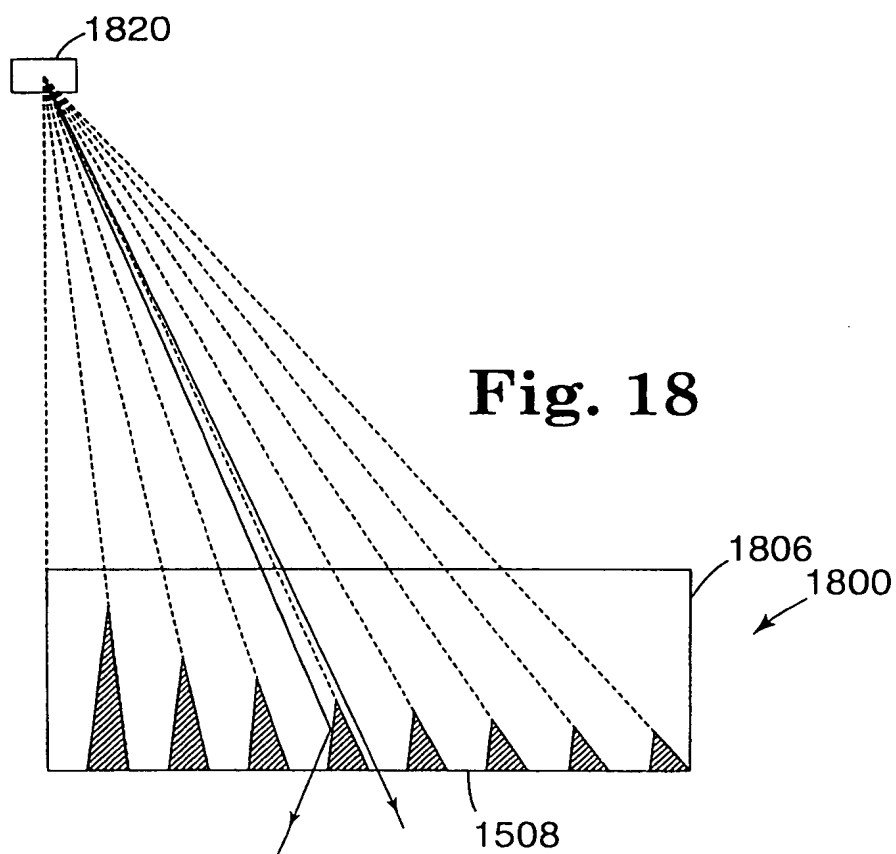


Fig. 17

13/16



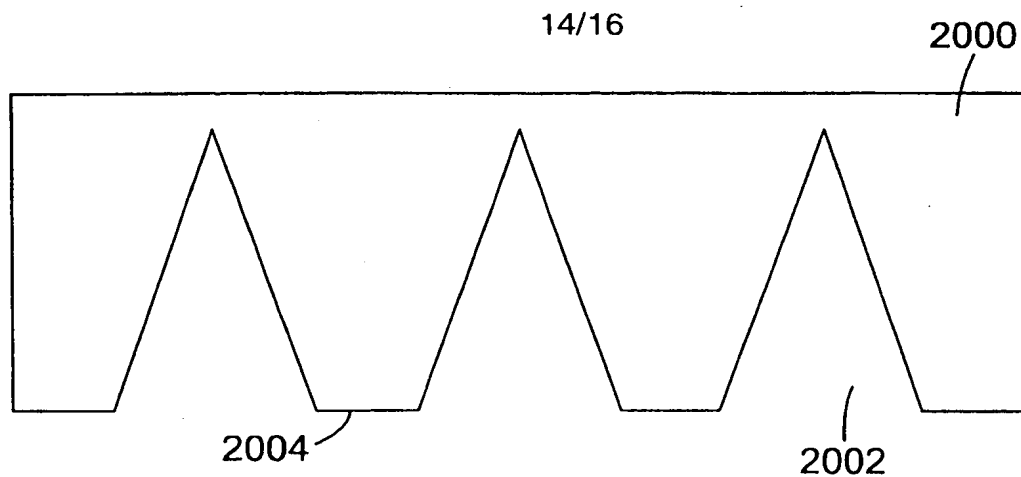


Fig. 20A

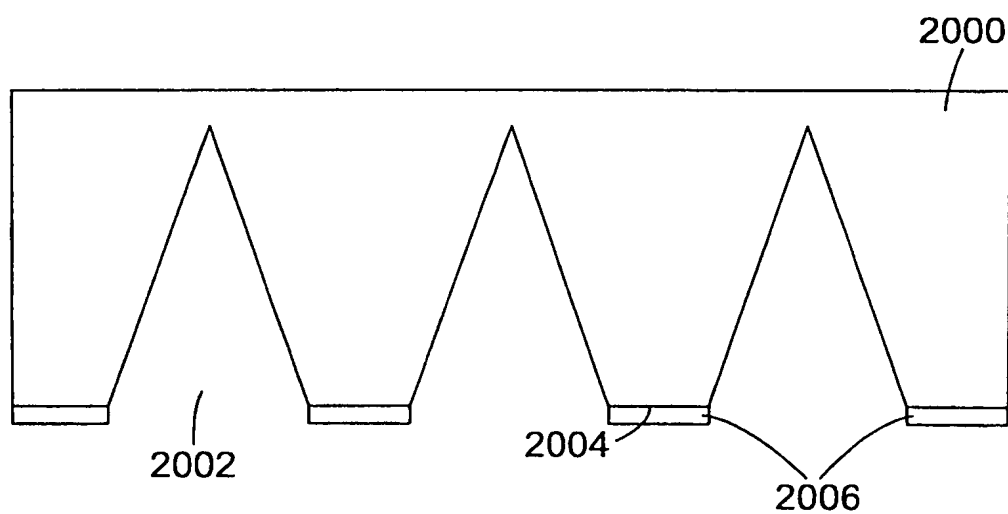


Fig. 20B

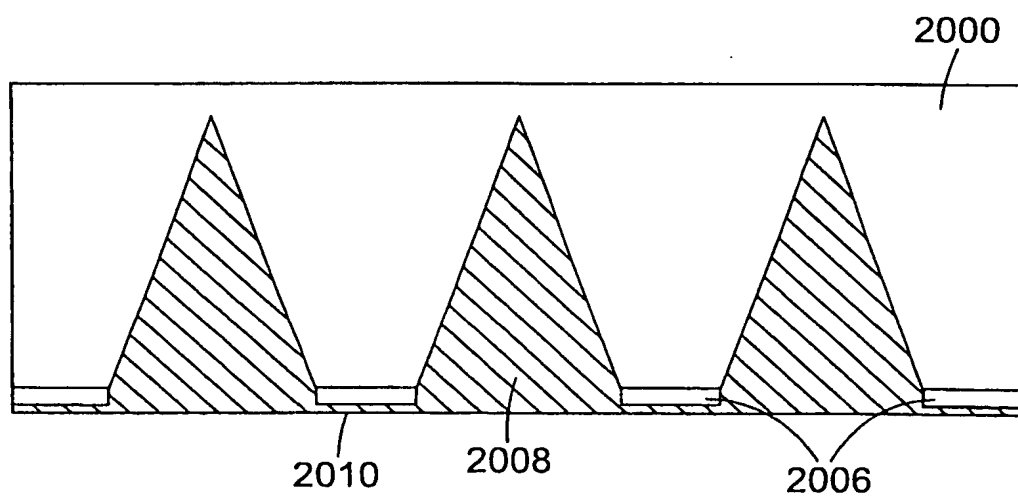


Fig. 20C

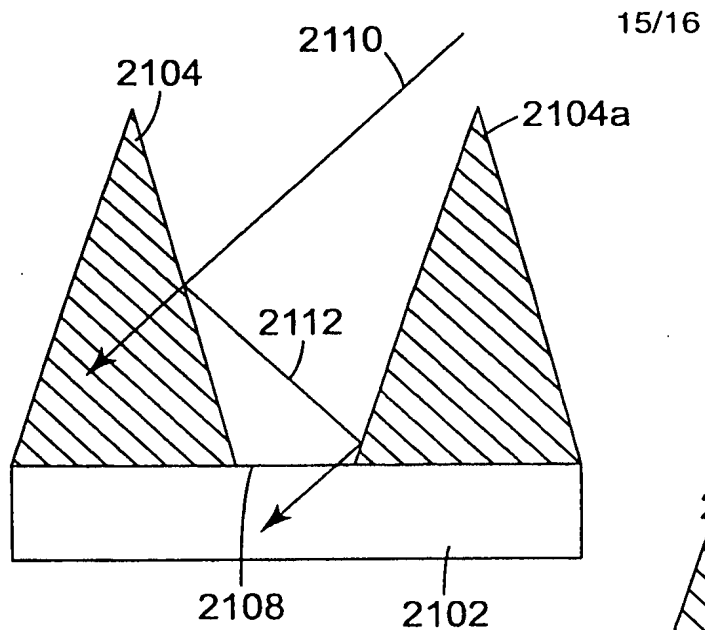


Fig. 21A

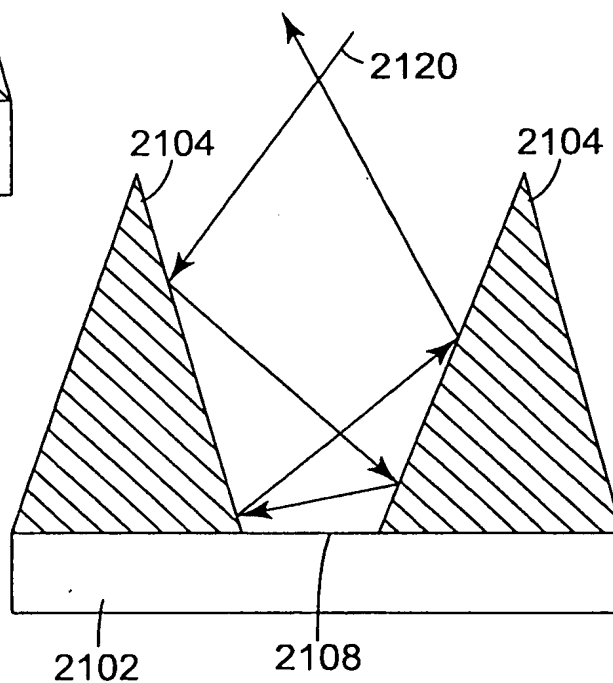


Fig. 21B

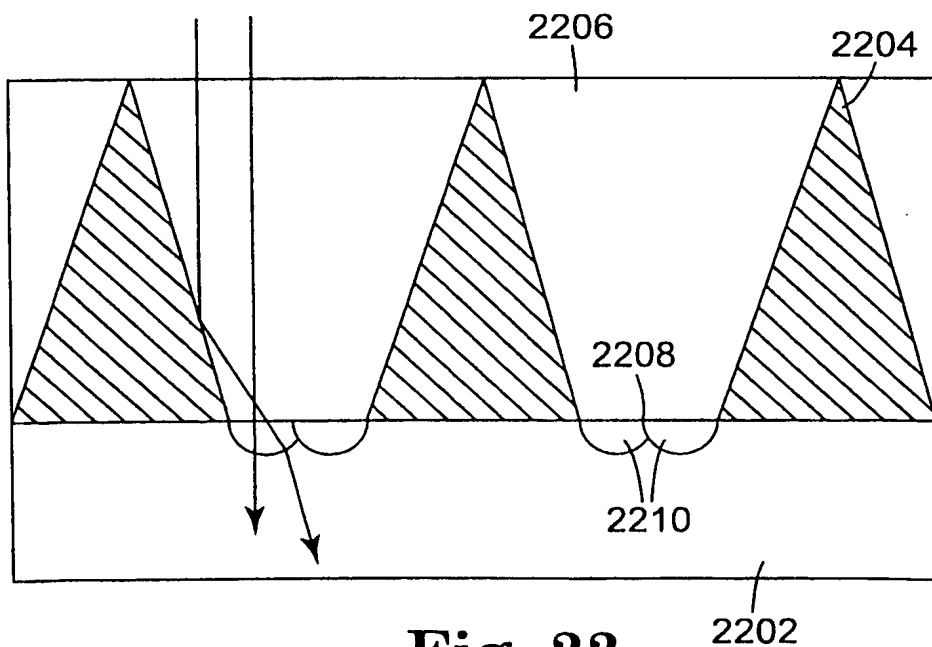
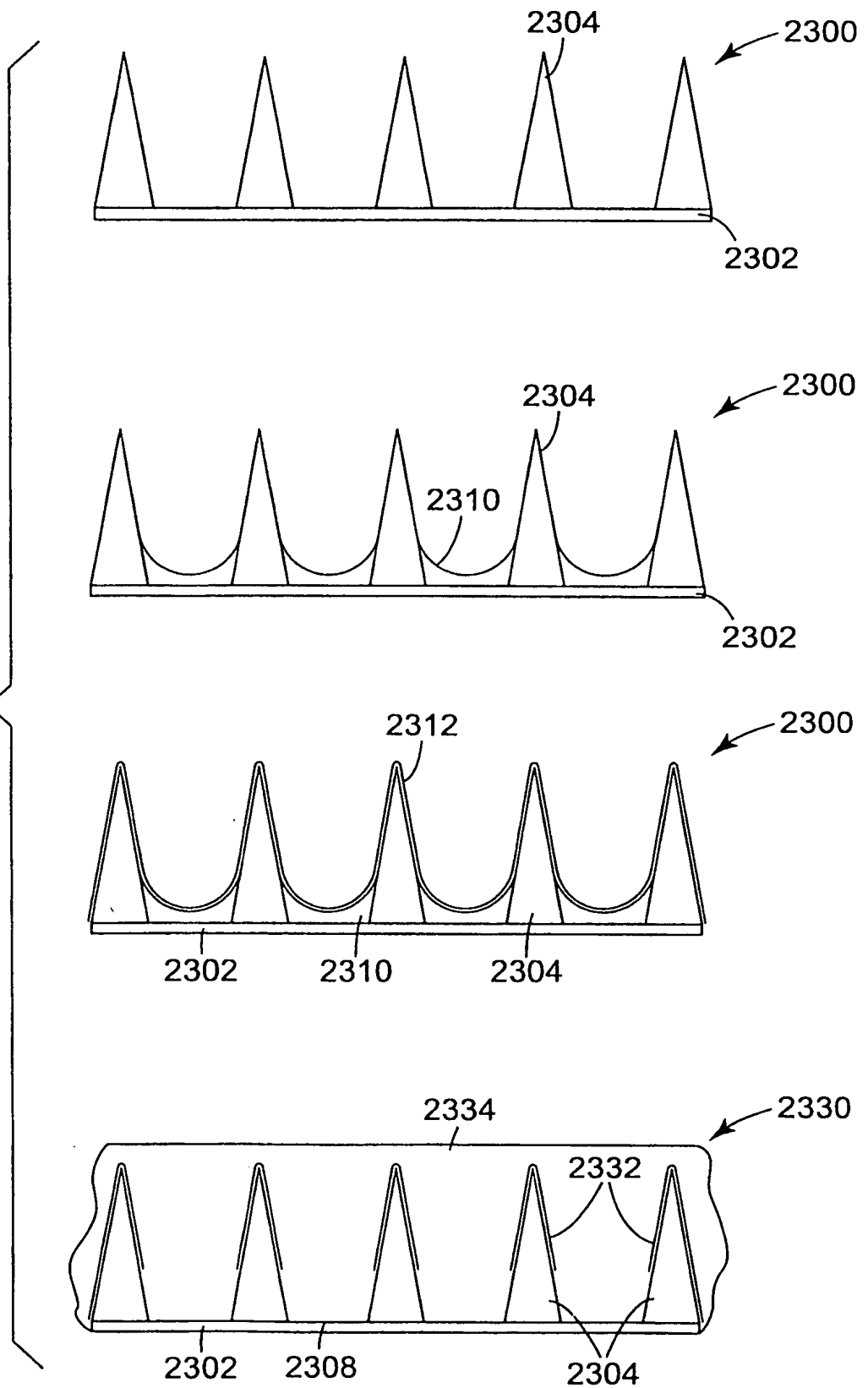


Fig. 22

16/16

Fig. 23



INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/27250

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G03B21/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI PAJ EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 573 764 A (BRADLEY RALPH H) 4 March 1986 (1986-03-04) the whole document ---	1-67
A	US 5 768 014 A (LEE DONG-HEE) 16 June 1998 (1998-06-16) the whole document ---	1-67
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 221 (P-386), 7 September 1985 (1985-09-07) & JP 60 079343 A (MITSUBISHI RAYON KK), 7 May 1985 (1985-05-07) abstract --- -/-	1-67



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *G* document member of the same patent family

Date of the actual completion of the international search

17 March 2000

Date of mailing of the international search report

14. 04. 00

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Björn Kallstenius

INTERNATIONAL SEARCH REPORT

Intern al Application No PCT/US 99/27250

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PATENT ABSTRACTS OF JAPAN vol. 012, no. 309 (P-748), 23 August 1988 (1988-08-23) & JP 63 080241 A (MITSUBISHI RAYON CO LTD), 11 April 1988 (1988-04-11) abstract</p> <p style="text-align: center;">-----</p>	1-67

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/27250

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4573764 A	04-03-1986	CA 1253725 A DE 3486212 D DE 3486212 T DK 609684 A,B, EP 0148529 A JP 1741215 C JP 4026454 B JP 60159733 A KR 9406725 B	09-05-1989 28-10-1993 07-04-1994 01-07-1985 17-07-1985 15-03-1993 07-05-1992 21-08-1985 27-07-1994
US 5768014 A	16-06-1998	KR 177648 B CN 1165317 A DE 19627105 A GB 2302963 A,B JP 9034017 A	01-05-1999 19-11-1997 09-01-1997 05-02-1997 07-02-1997
JP 60079343 A	07-05-1985	NONE	
JP 63080241 A	11-04-1988	JP 1766804 C JP 4055490 B	11-06-1993 03-09-1992



US006049649A

United States Patent [19]

Arai

[11] **Patent Number:** **6,049,649**[45] **Date of Patent:** **Apr. 11, 2000**[54] **SURFACE LIGHT SOURCE DEVICE OF SIDE-LIGHT TYPE**[75] **Inventor:** Takayuki Arai, Kasukabe, Japan[73] **Assignees:** Enplas Corporation, Kawaguchi;
Yasuhiro Koike, Yokohama, both of Japan[21] **Appl. No.:** 08/823,488[22] **Filed:** Mar. 25, 1997[30] **Foreign Application Priority Data**

Mar. 28, 1996 [JP] Japan 8-097329

[51] **Int. Cl.⁷** G02B 6/10[52] **U.S. Cl.** 385/133; 359/251; 349/62;
353/81; 362/31[58] **Field of Search** 385/133; 362/31;
349/5, 62, 82; 359/455-456, 619, 40, 251;
353/81[56] **References Cited****U.S. PATENT DOCUMENTS**

5,396,350	3/1995	Beeson et al. .	
5,428,468	6/1995	Zimmerman et al. .	
5,598,280	1/1997	Nishio et al.	349/57
5,598,281	1/1997	Zimmerman et al.	349/5
5,671,994	9/1997	Tai et al.	362/31
5,841,572	11/1998	Ando et al.	359/456

Primary Examiner—Rodney Bovernick*Assistant Examiner*—Ellen E. Kang*Attorney, Agent, or Firm*—Staas & Halsey LLP[57] **ABSTRACT**

A surface light source device of side-light type enables concentrated output of illumination light to a frontal direction. A flux having clear directivity is outputted from window portions 1w on an emitting surface 5 of a light guide plate 1 with emitting directivity. This flux is represented by a beam C01 outputted in a direction at an angle of 70°. A flux C02 incident on reflection portions 1r is returned to the light guide plate 1 and is given an opportunity of output from the window portions 1w again. The flux C01 having escaped from the window portions 1w to an air layer AR is obliquely incident on flat regions 14g of a propagation direction characteristics modifier 14, and a degree of parallelization of the flux in a propagation direction is improved. The flux is blocked by the reflection portions 1r from being incident on a notch portion (uneffective area) between the flat regions 14g. After total reflection by a total reflection surface 14b of each projection element 14c, the flux is outputted from a flat outside surface 14h to a frontal direction without degrading the improved degree of parallelization. The projection elements 14c may be two-dimensionally arrayed. A prismatic groove or a cylindrical lens array may be formed on the outside surface 14h to two-dimensionally enhance the degree of parallelization.

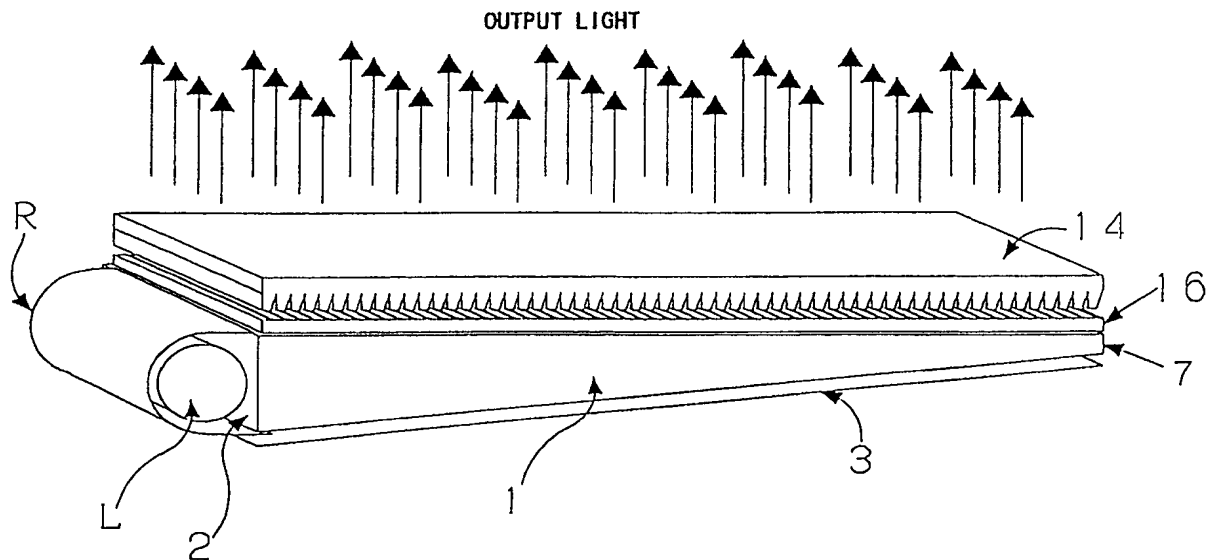
11 Claims, 23 Drawing Sheets

FIG. 1

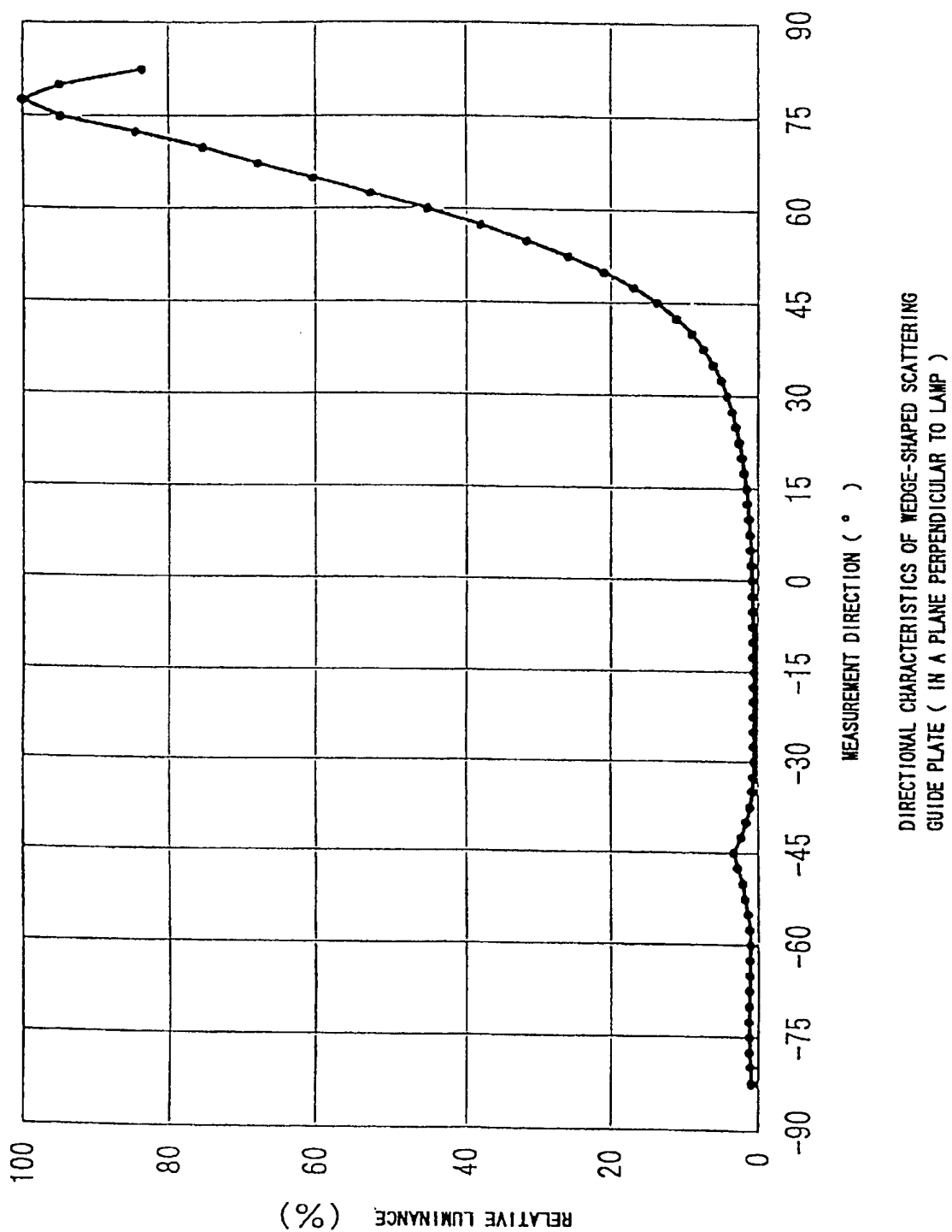


FIG. 2

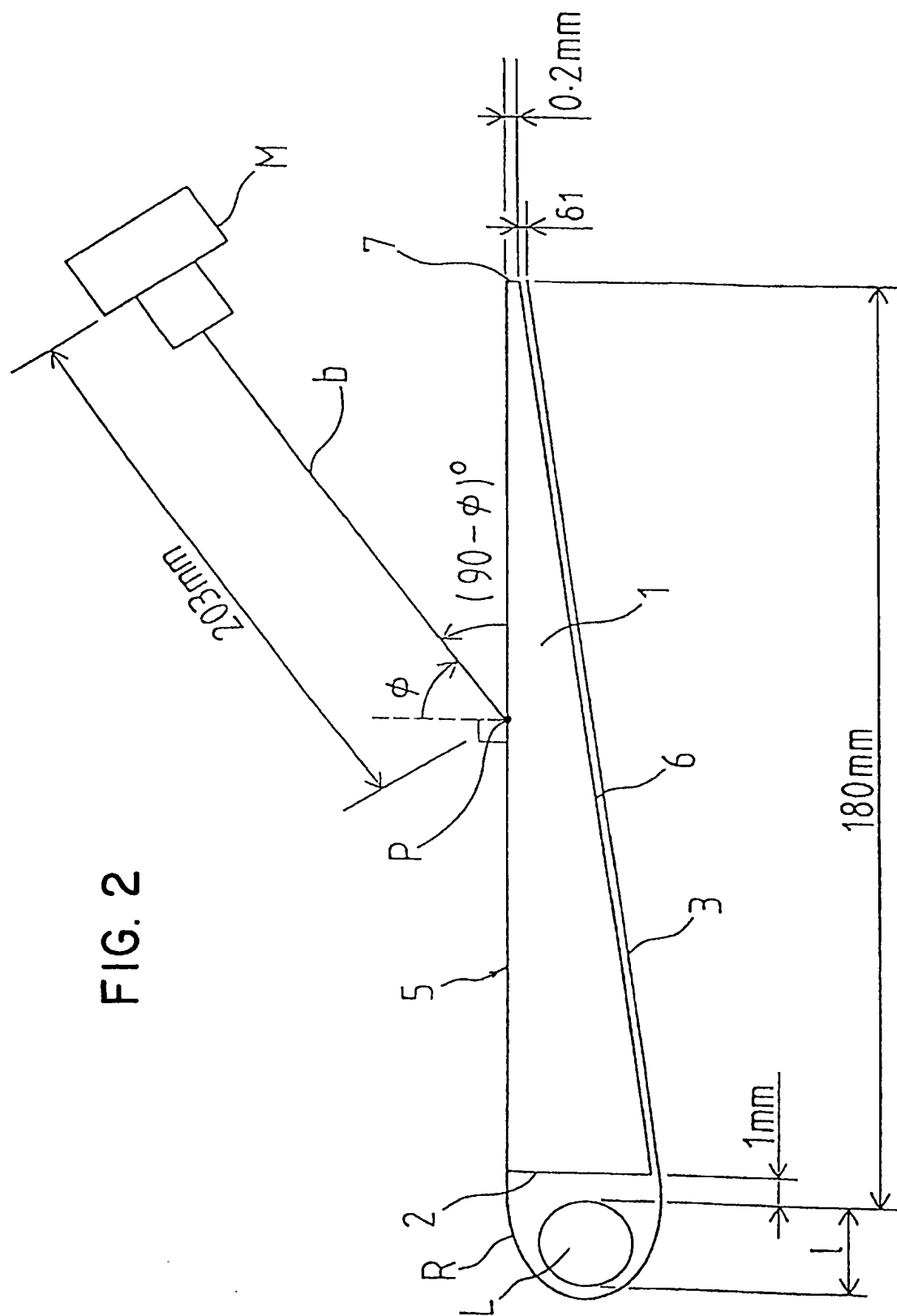


FIG. 3
(PRIOR ART)

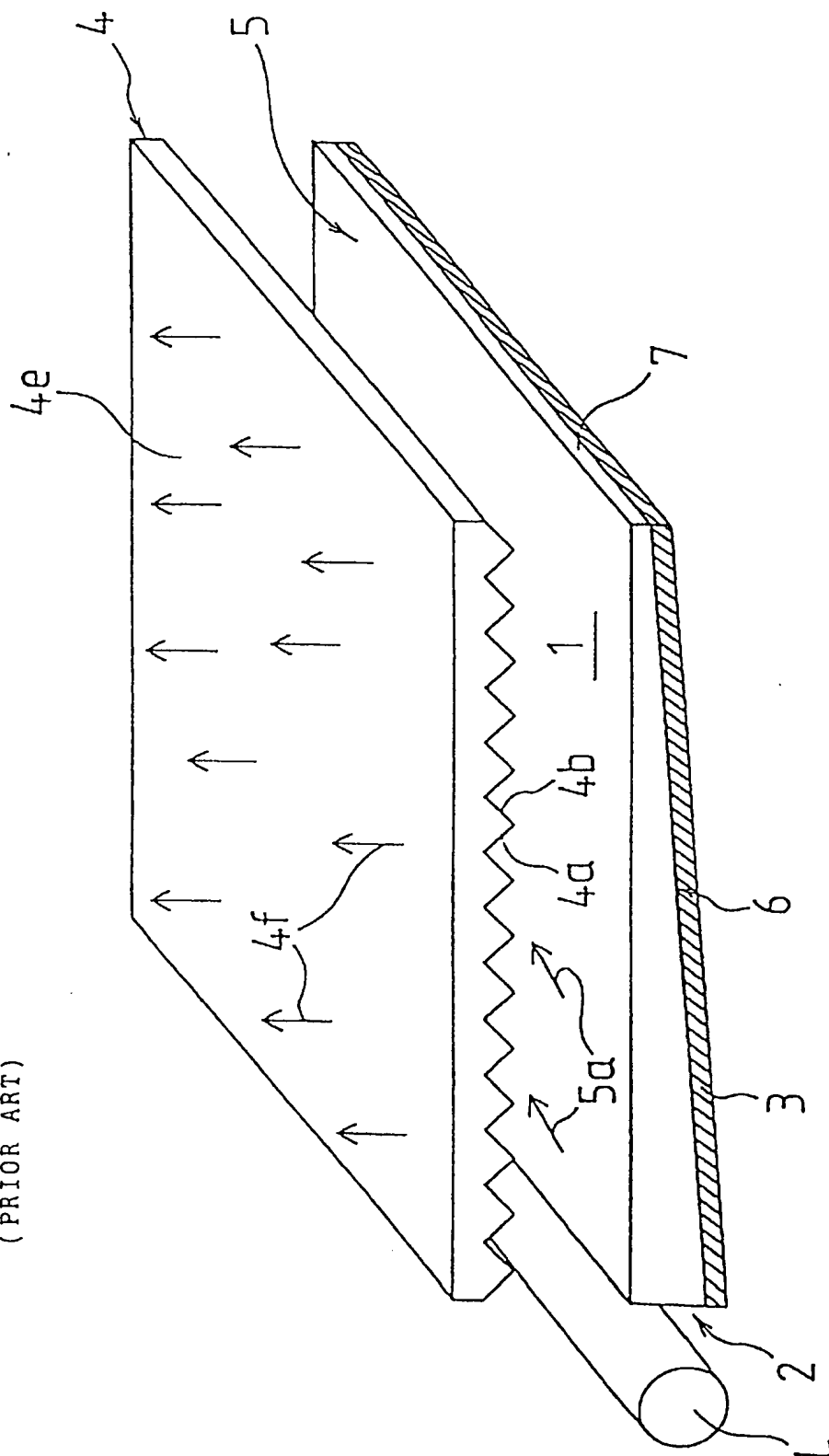


FIG. 4
(PRIOR ART)

FIG. 5
(PRIOR ART)

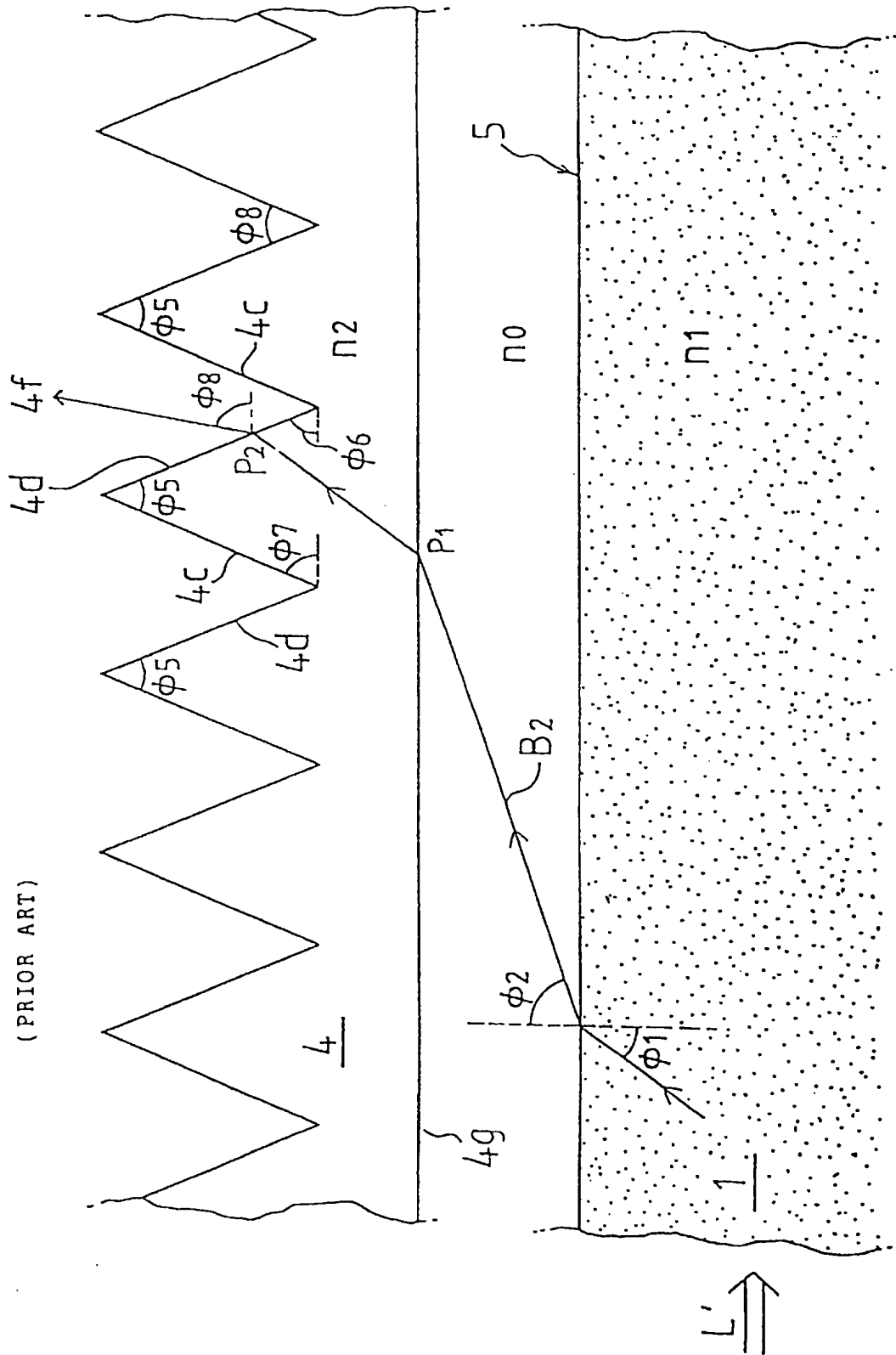


FIG. 6

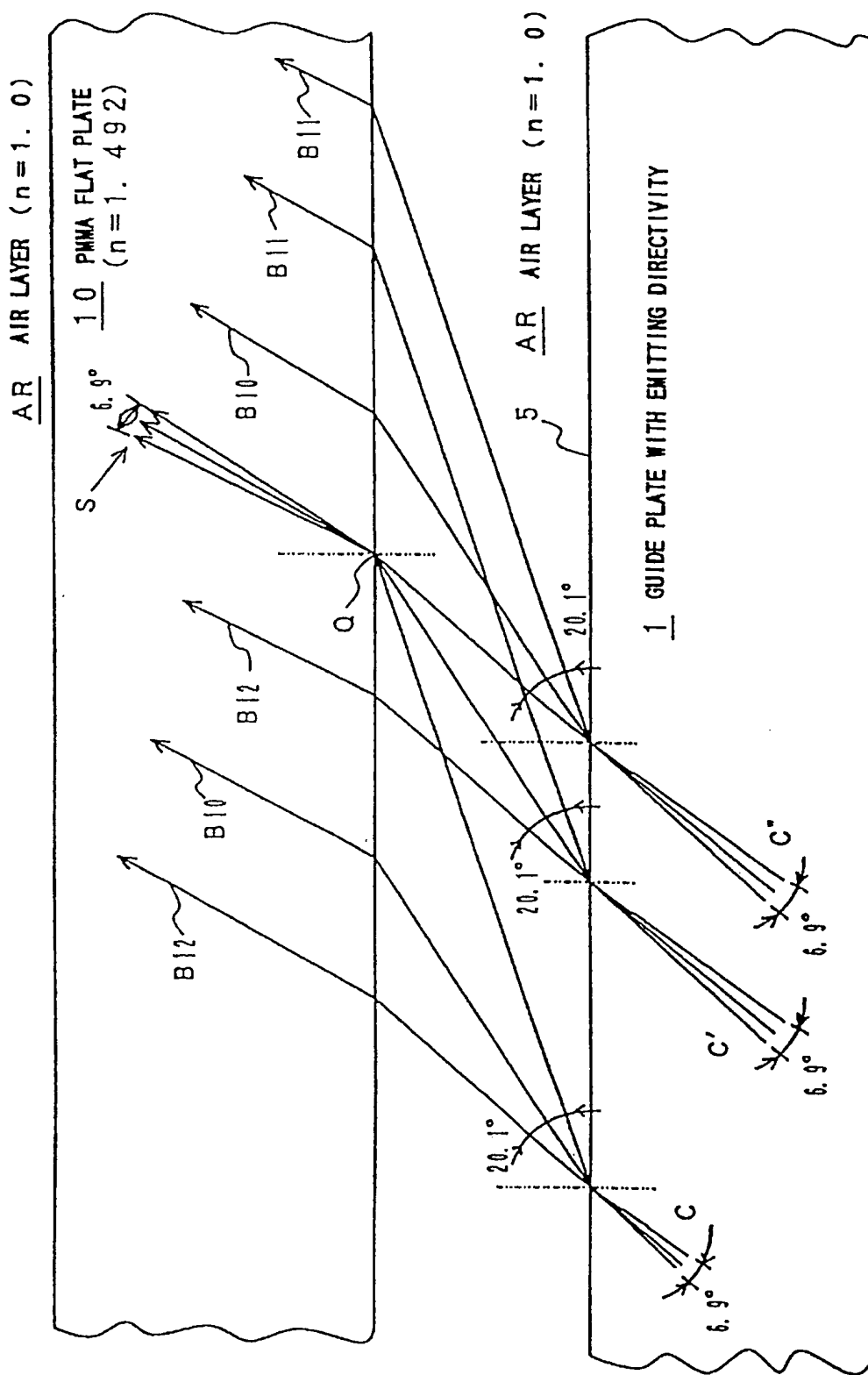


FIG. 7

(PRIOR ART)

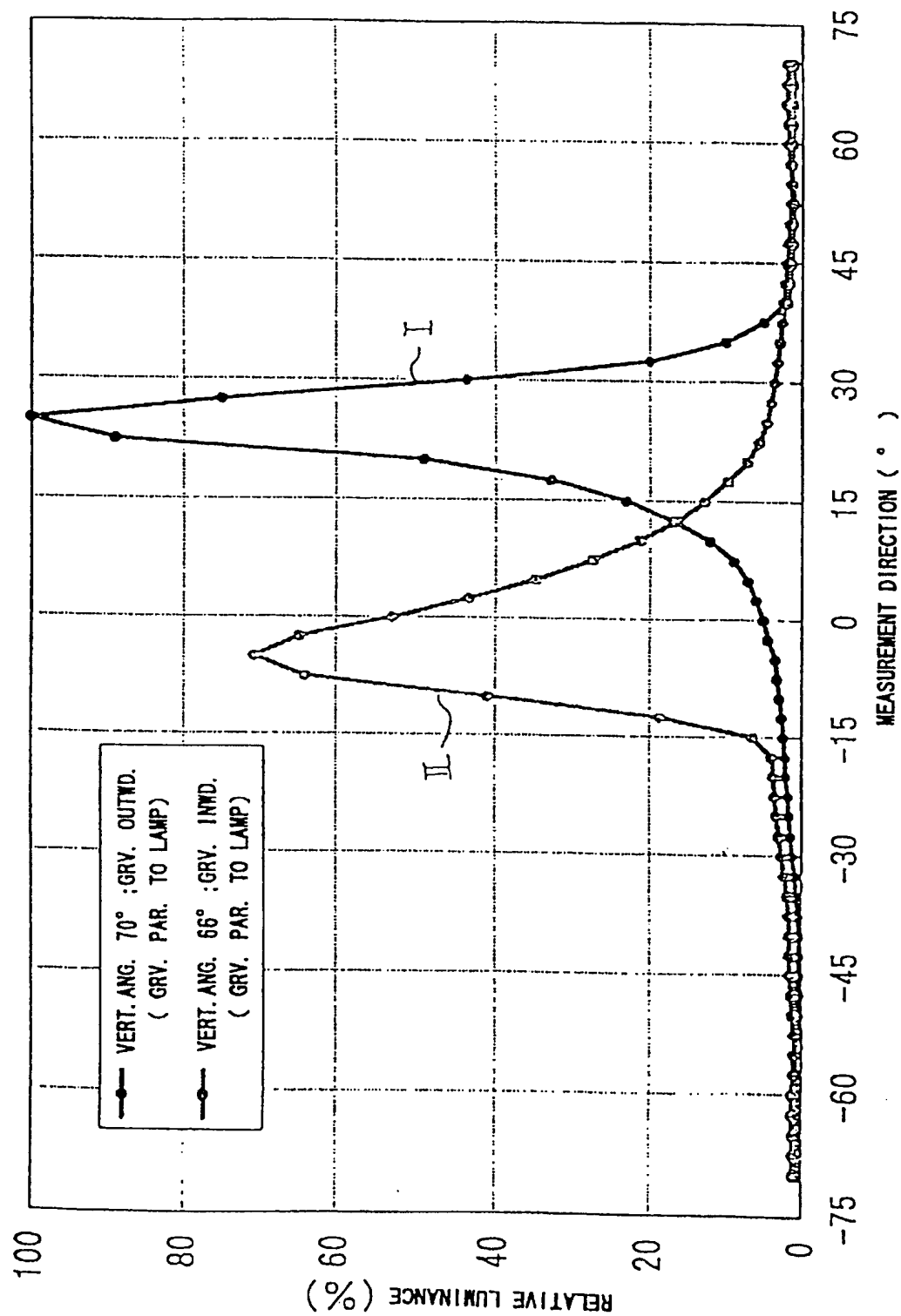


FIG. 8

(PRIOR ART)

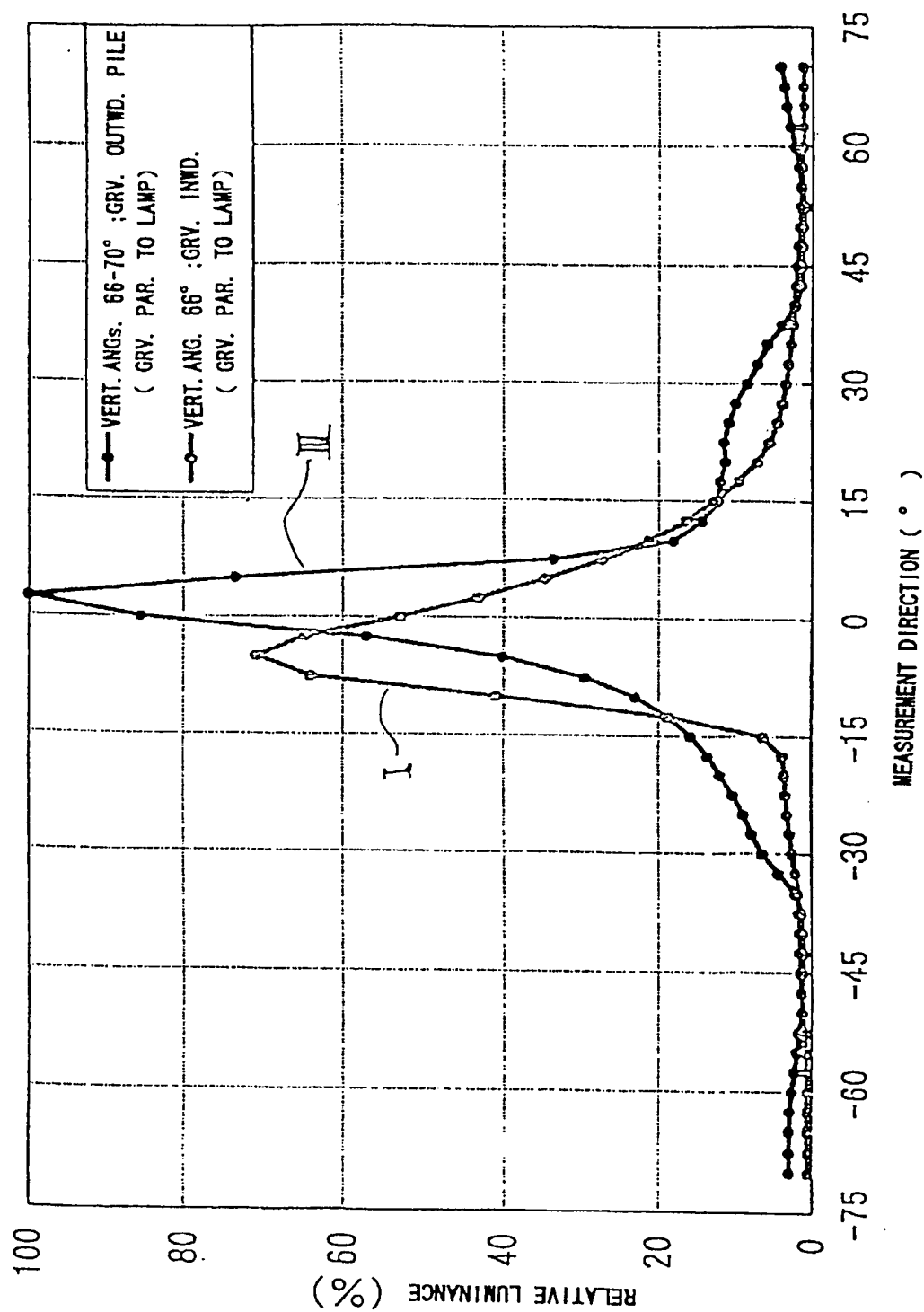


FIG. 9

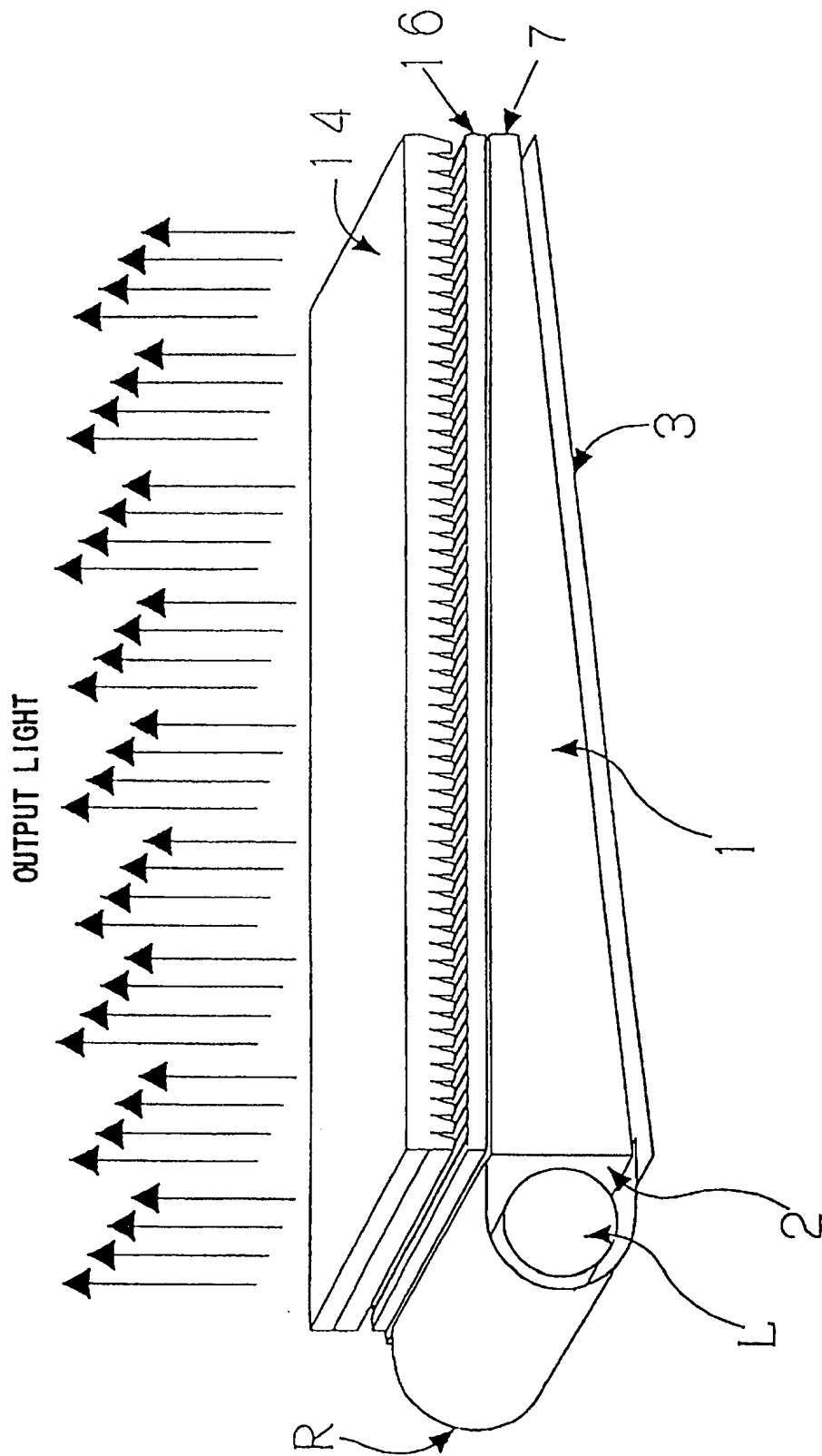


FIG. 10

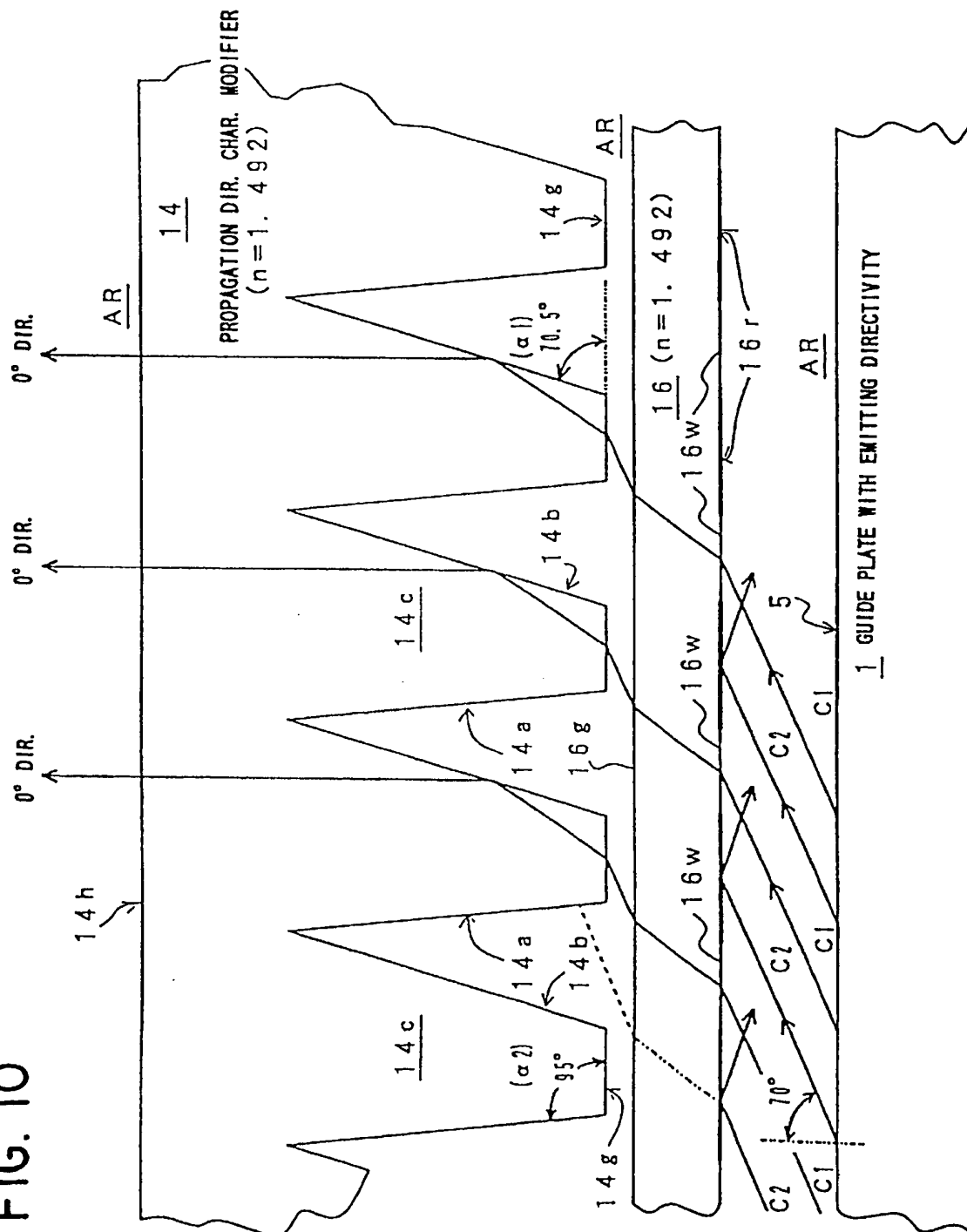


FIG. II

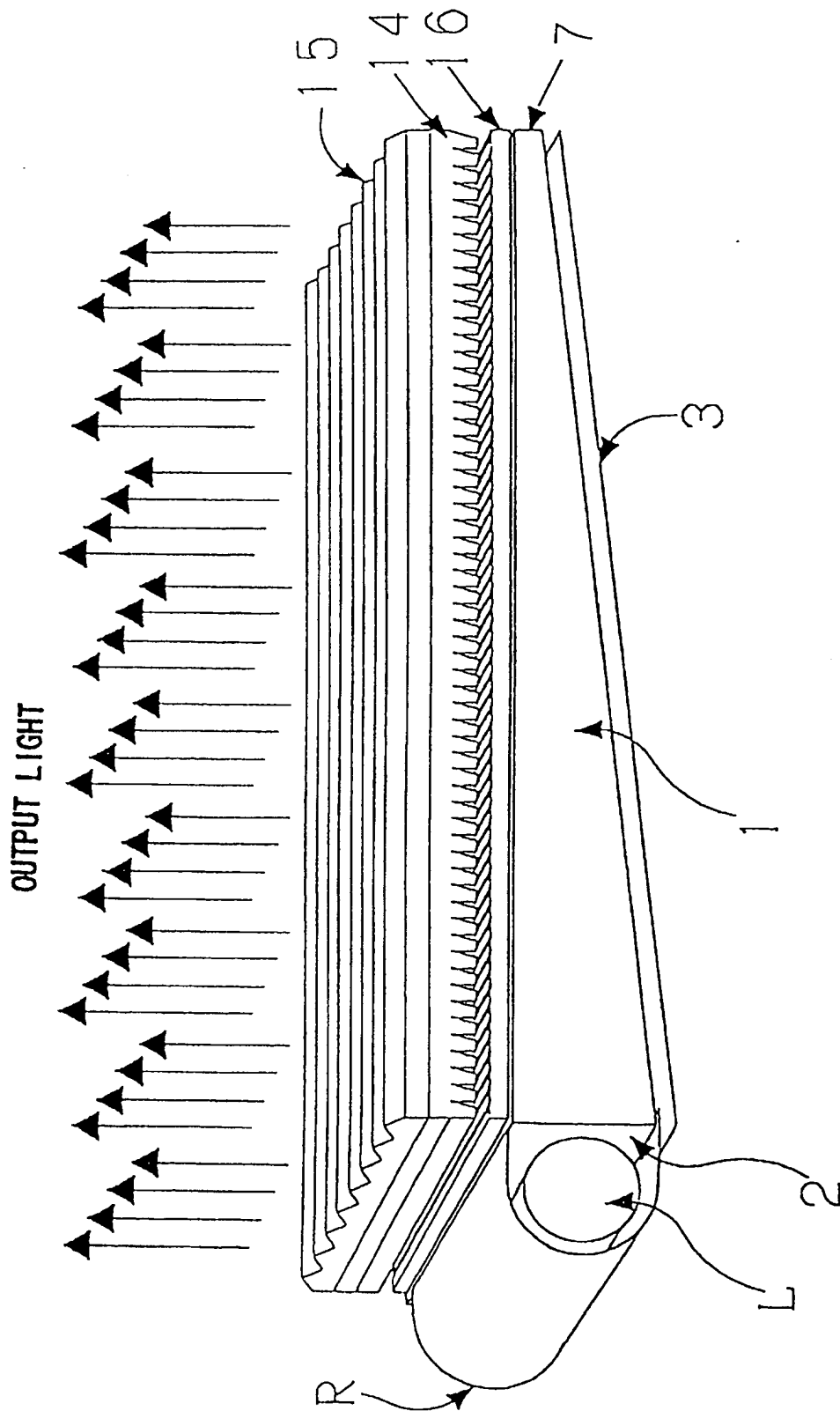


FIG. 12

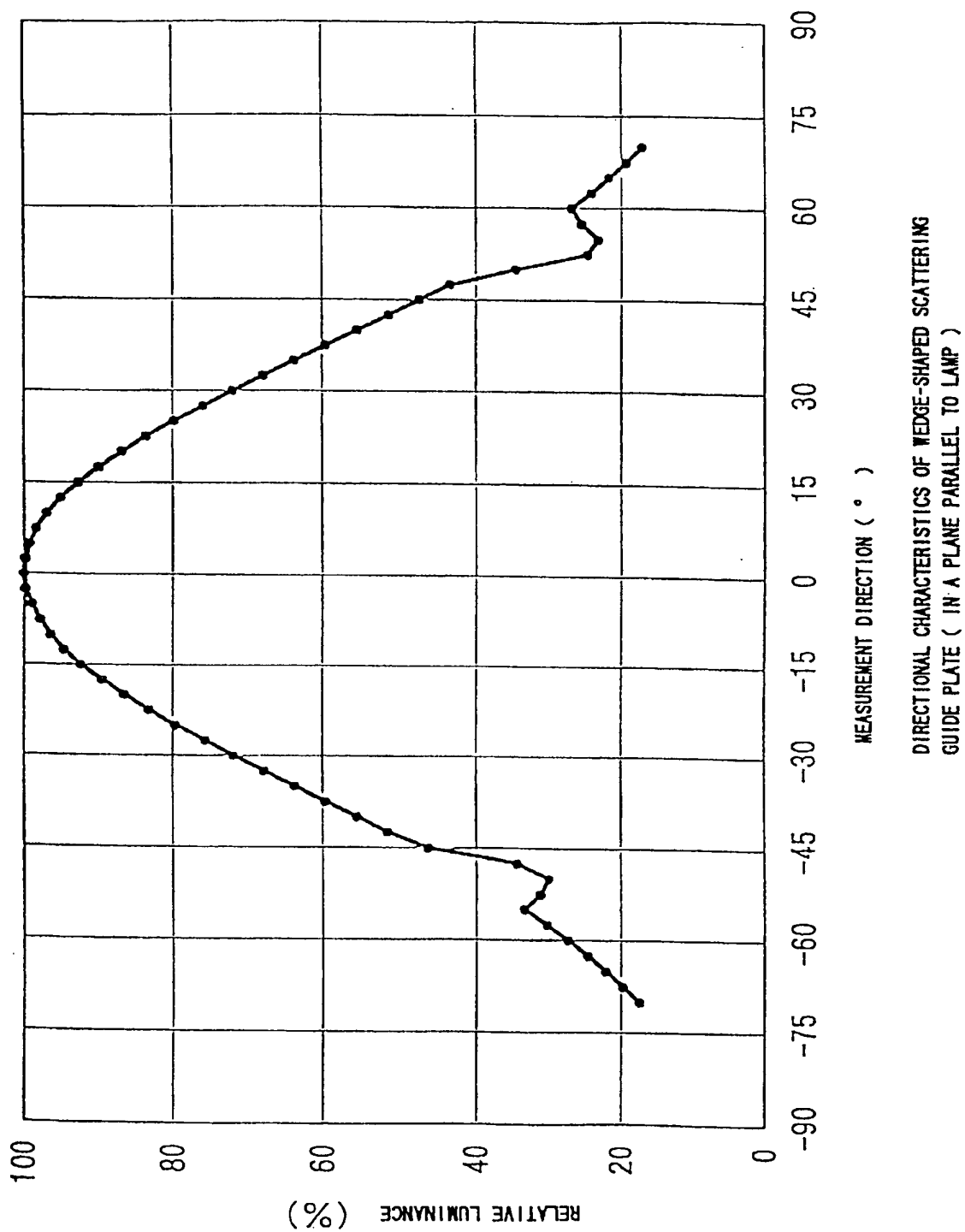


FIG. 13

OUTPUT LIGHT

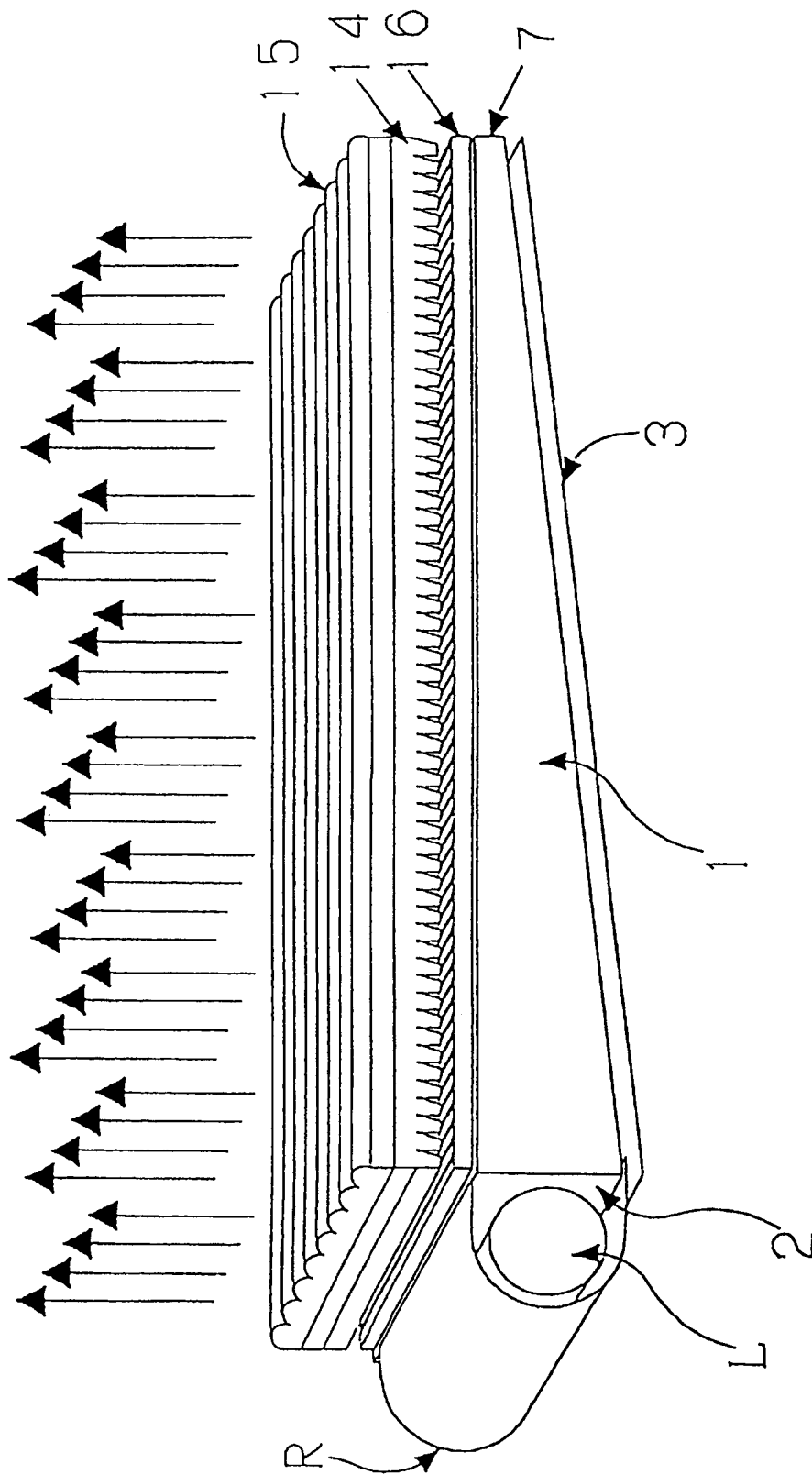


FIG. 14

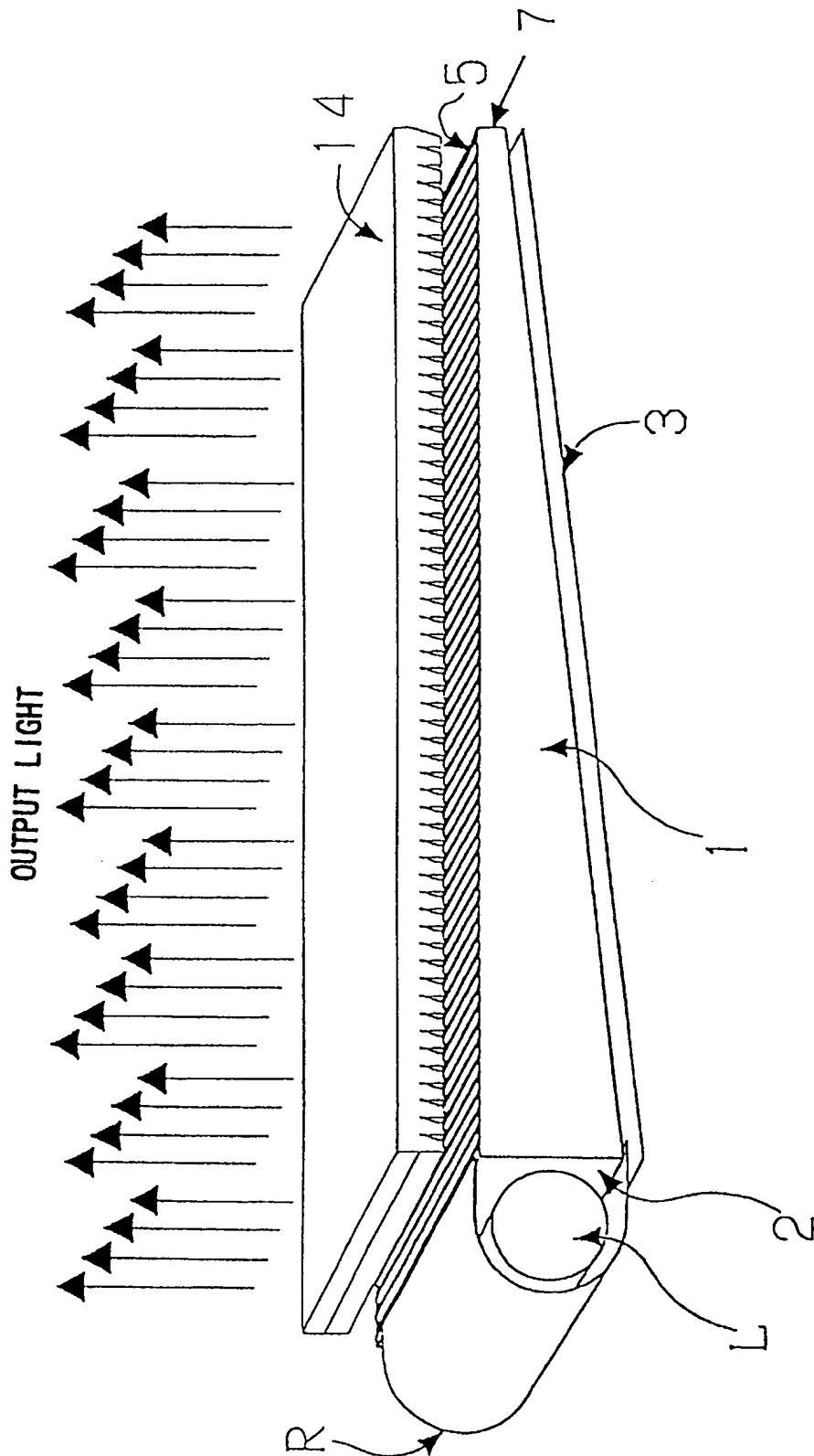


FIG. 16

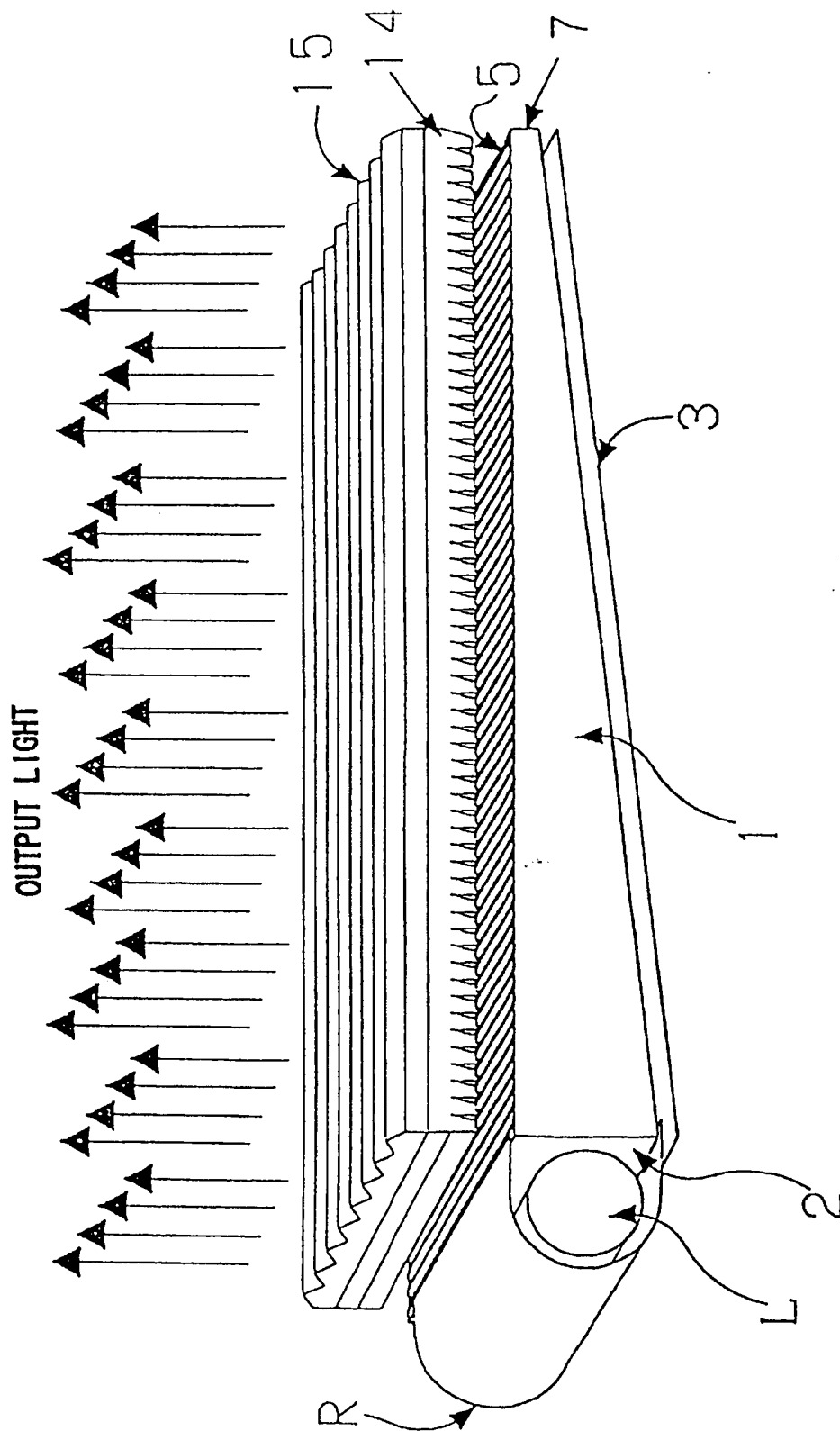


FIG. 17

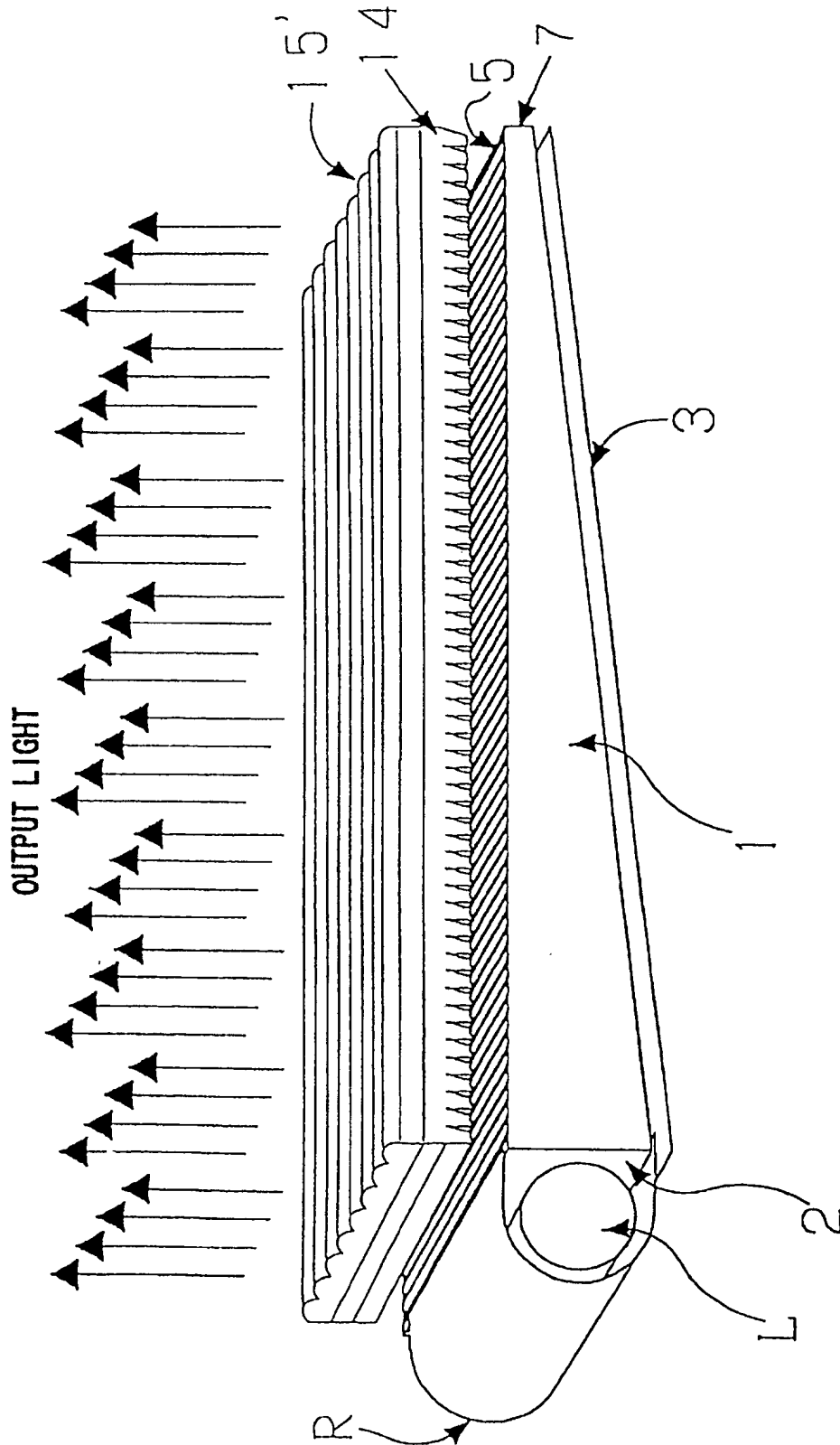


FIG. 18B

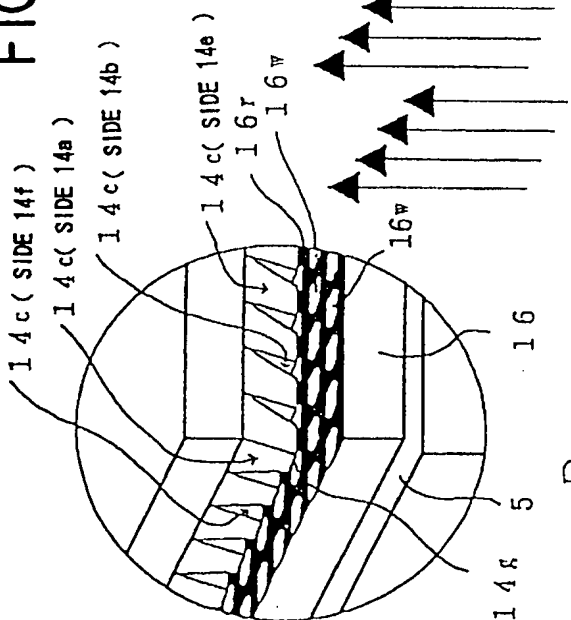


FIG. 18A

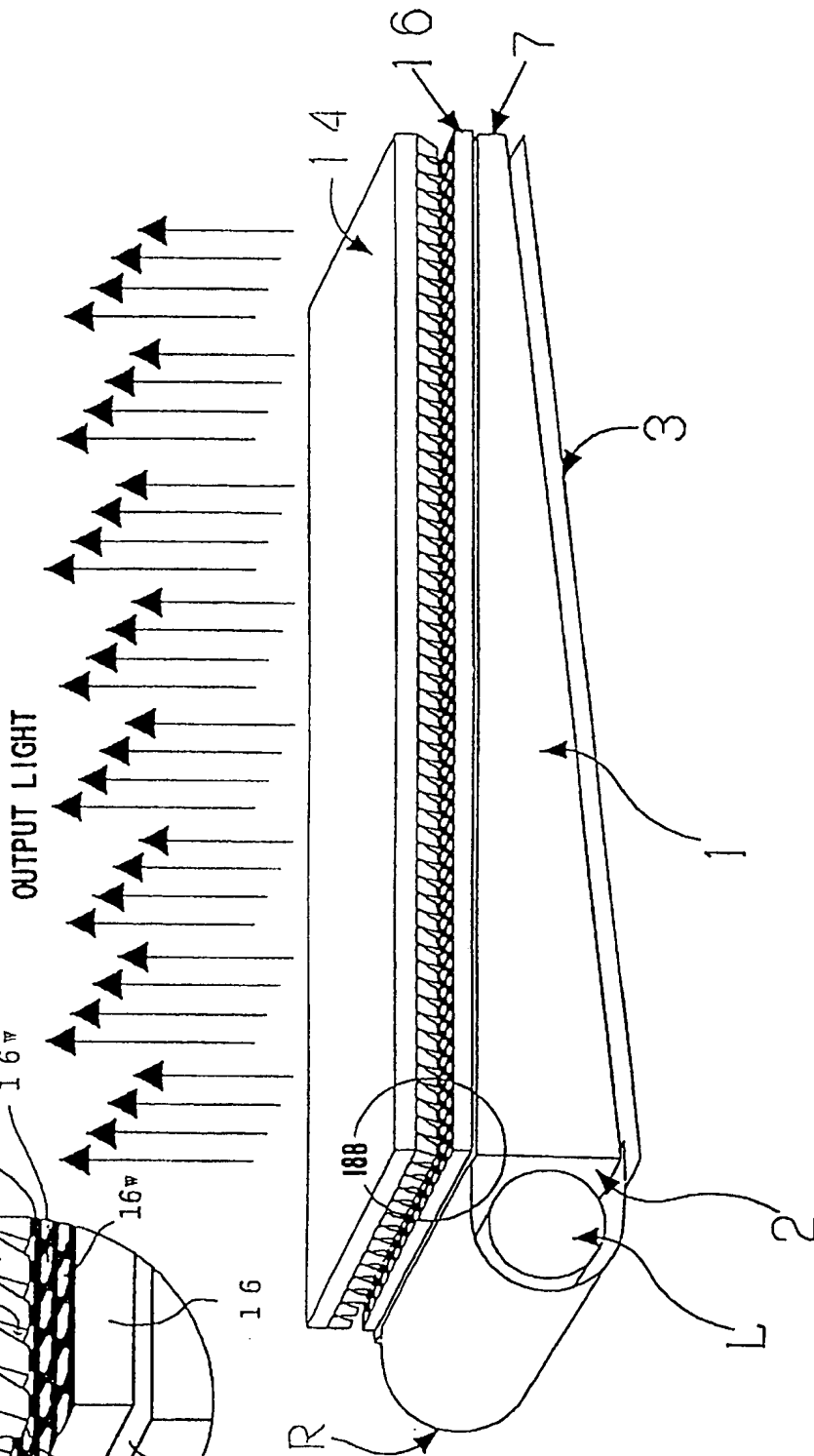


FIG. 19B

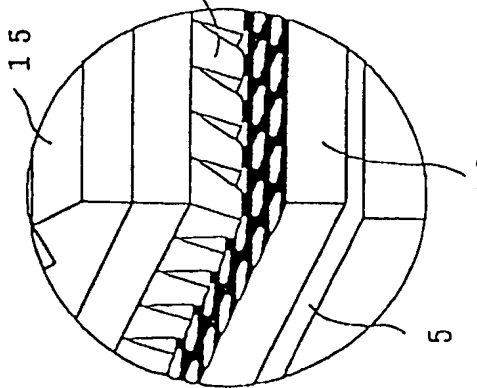


FIG. 19A

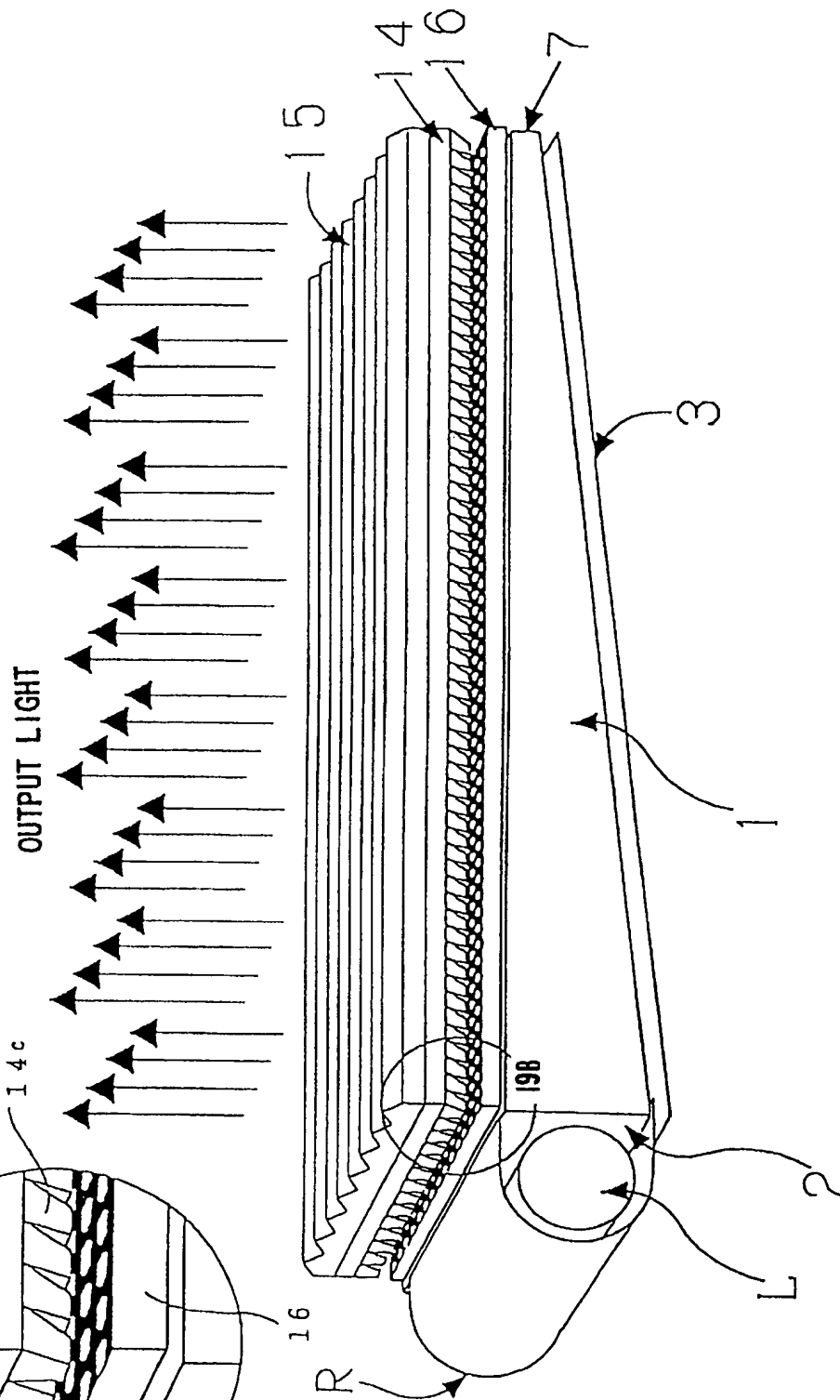


FIG. 20B

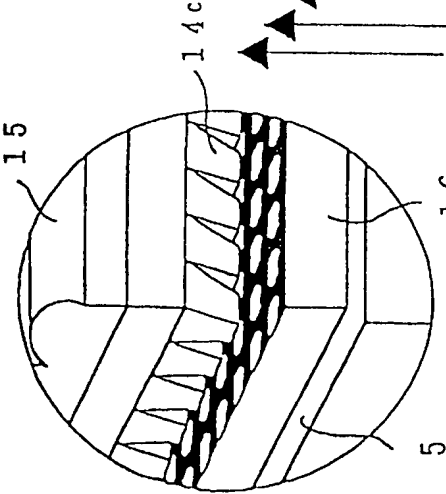


FIG. 20A

OUTPUT LIGHT

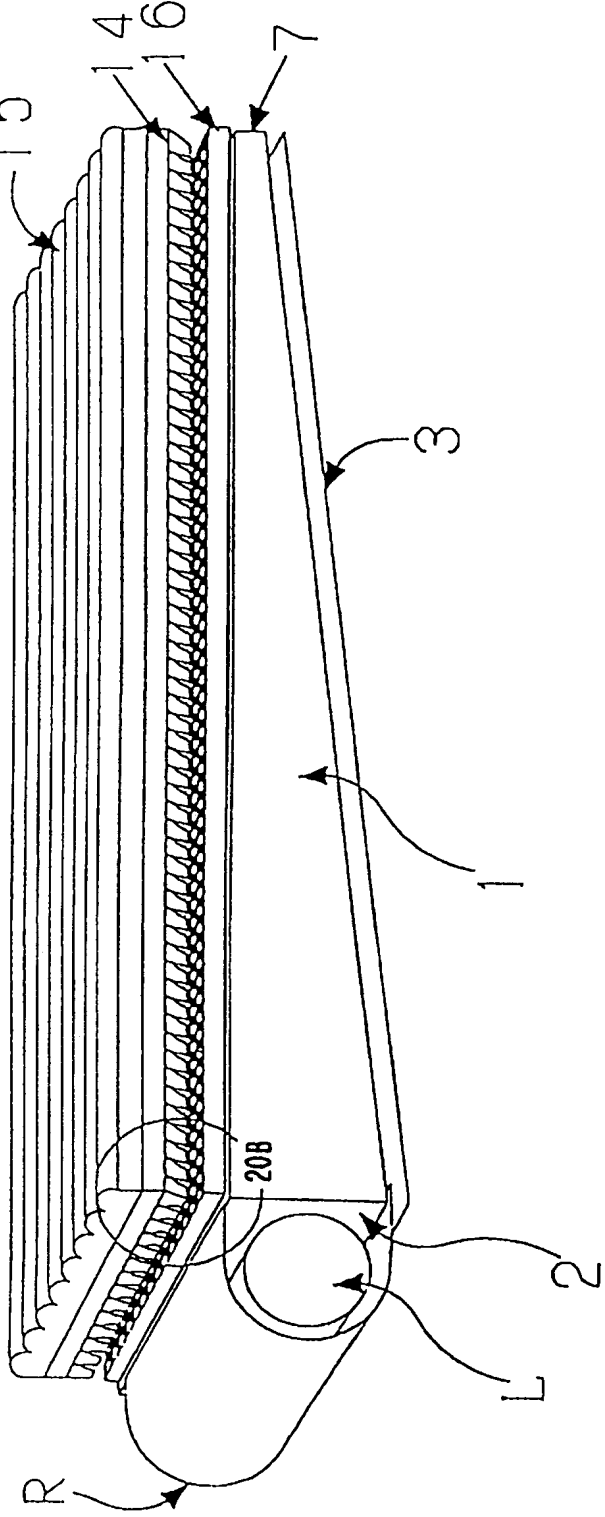
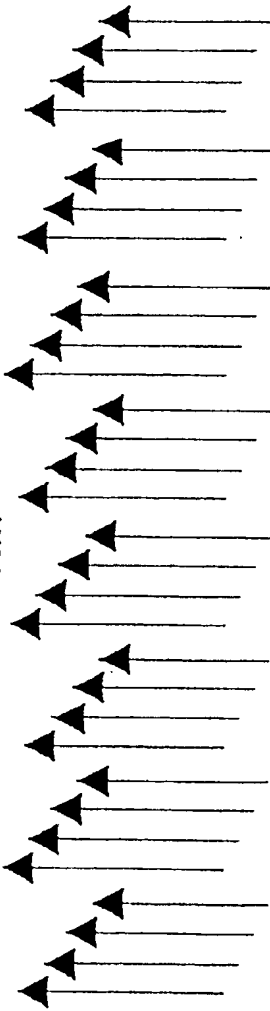


FIG. 2IB

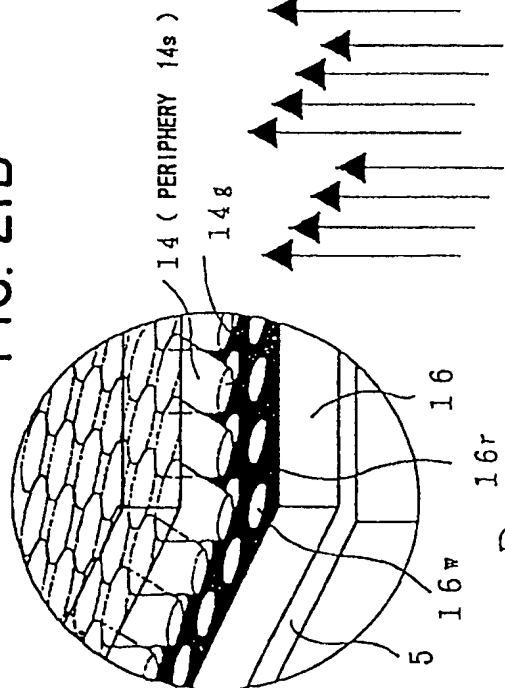


FIG. 2IA

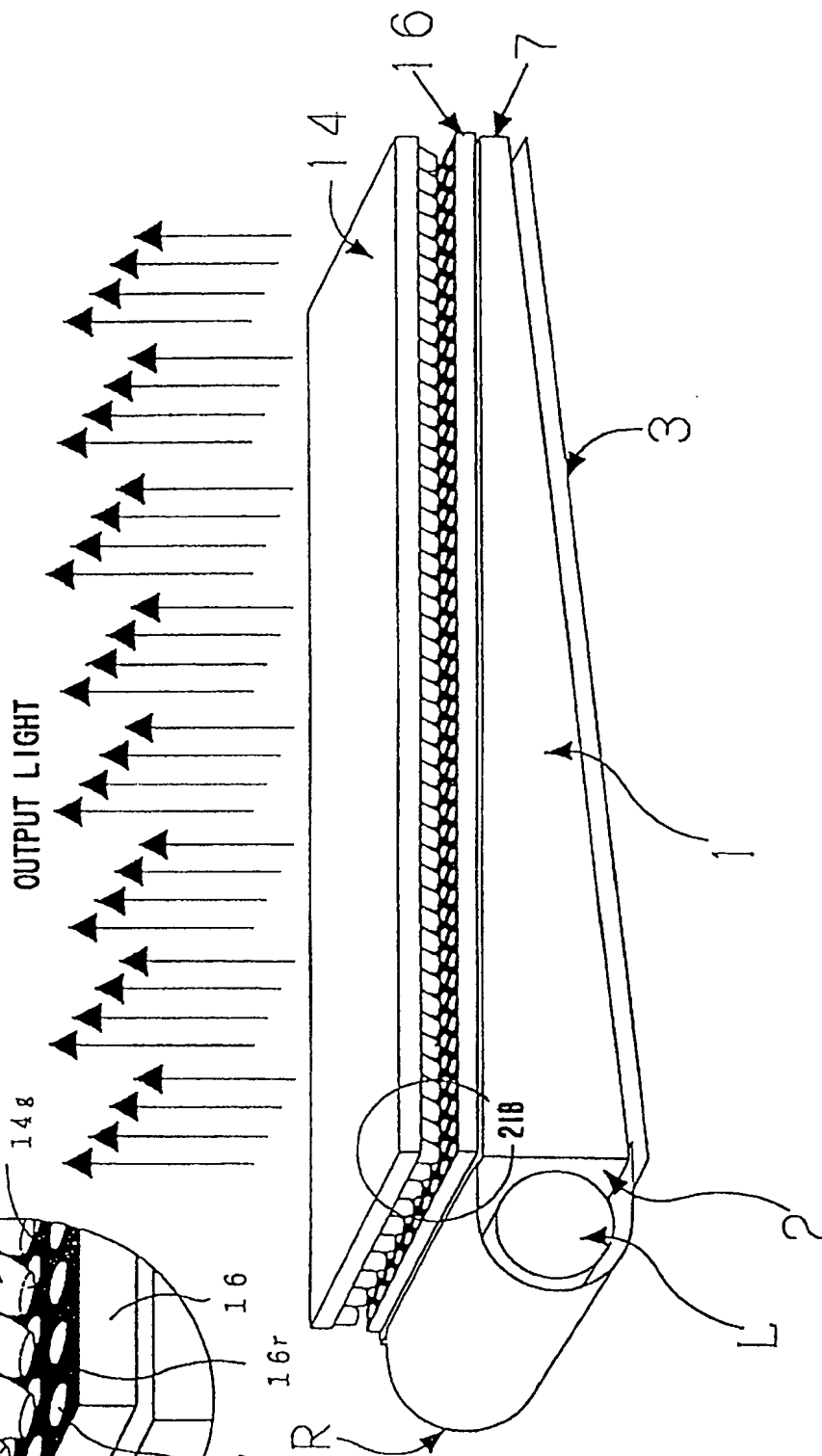


FIG. 22B

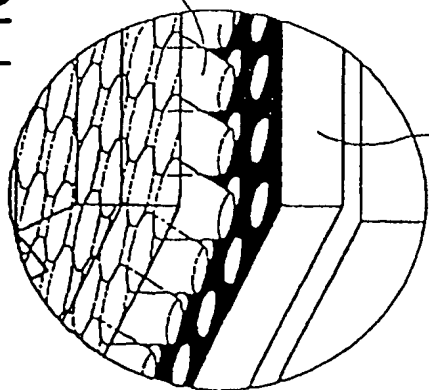


FIG. 22A

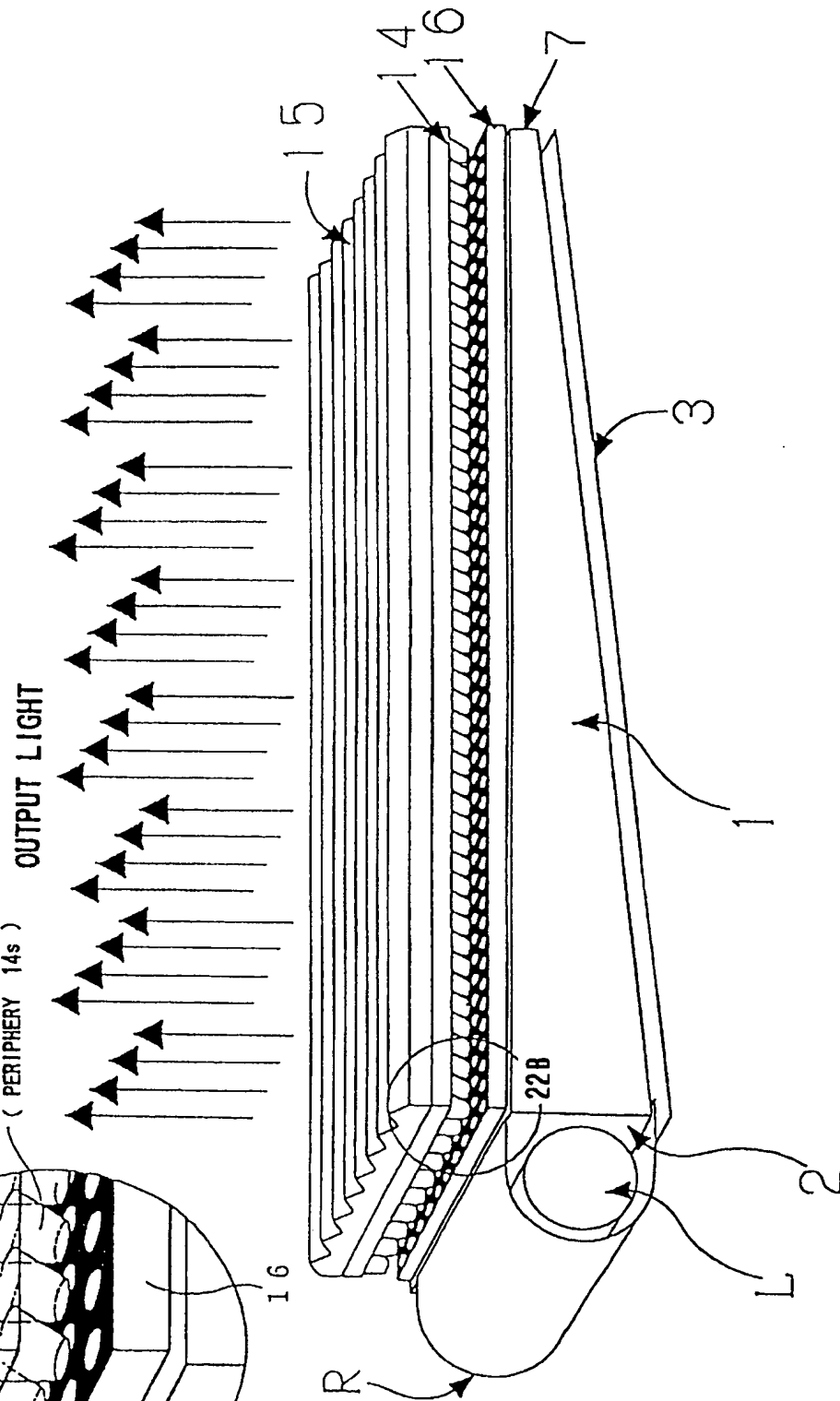
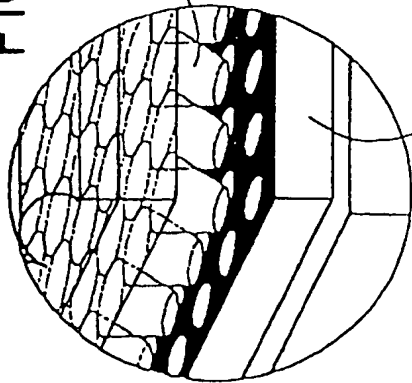
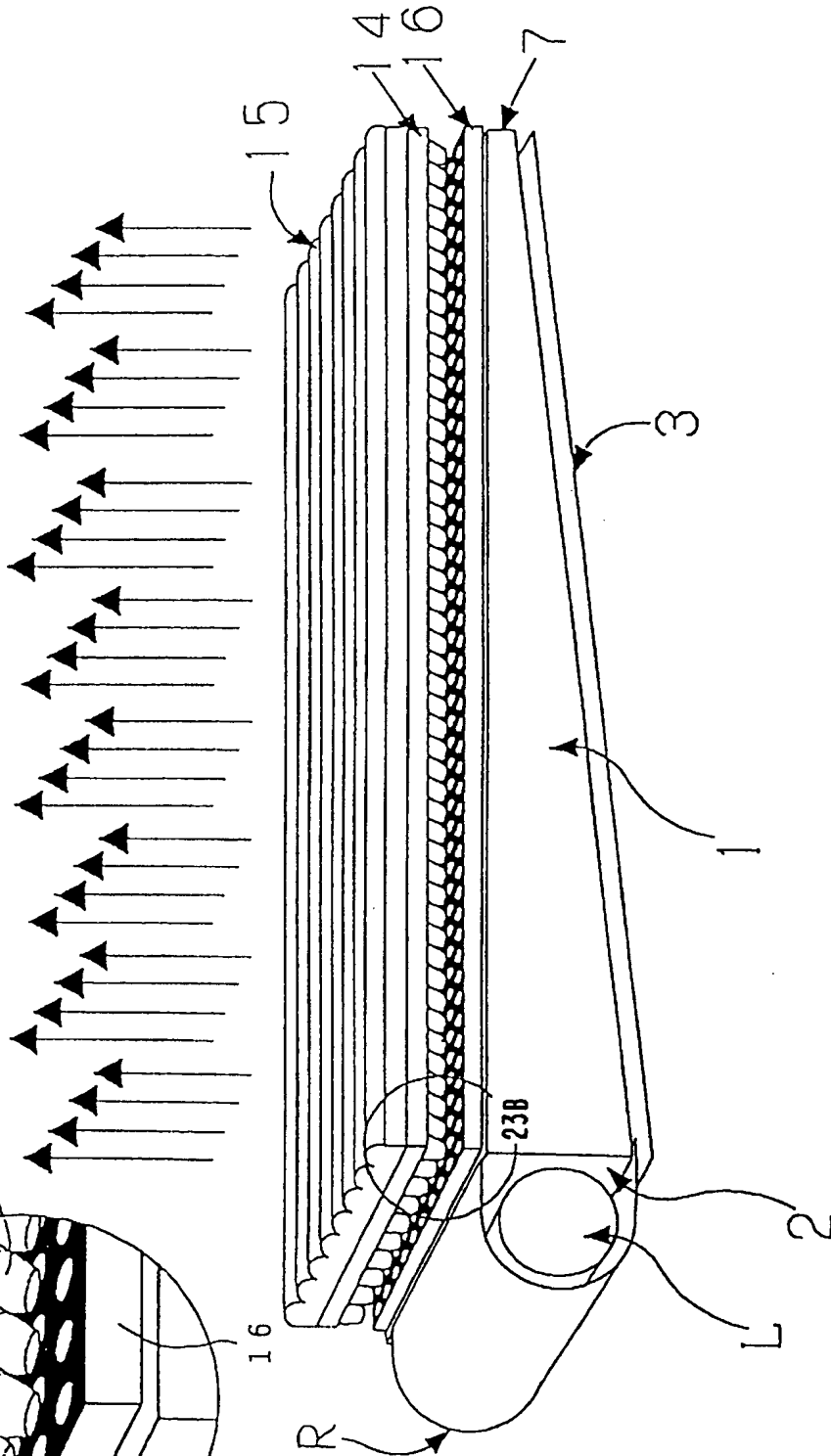


FIG. 23B



14c (PERIPHERY 14s) OUTPUT LIGHT

FIG. 23A



SURFACE LIGHT SOURCE DEVICE OF SIDE-LIGHT TYPE

BACKGROUND OF THE INVENTION

This invention relates to a surface light source device of side-light type adopting a light guide plate with emitting directivity and a propagation direction characteristics modifier in combination. The surface light source device of the present invention is effectively applicable to, for instance, a back lighting arrangement in a liquid crystal display requiring an illumination flux concentratively propagating to a frontal direction.

A well-known surface light source device of side-light type has a light source element such as a cold cathode tube disposed on the lateral side of a light guide plate and uses one surface of the light guide plate as an emitting surface. Such a surface light source device has properties of obtaining an illumination flux having a relatively large sectional area in a thin structure, and is widely applied to a back lighting arrangement in a liquid crystal display.

A light scattering and guiding material is well known as a material of the light guide plate. The light scattering and guiding material includes an optical element having scattering power obtained by distributing a microscopic structure of uneven refractive index inside a transparent optical material. The light guide plate made of the light scattering and guiding material is called a light scattering light guide plate. In general, a surface light source device of side-light type adopting the light scattering light guide plate has the advantage of obtaining a high efficiency of light utilization in a simple structure.

Unless the microscopic structure of uneven refractive index inside the light scattering light guide plate is made excessively small in size, clear directivity is added to an output flux from an emitting surface. A light guide plate meeting the above requirement is called "a light guide plate with emitting directivity" in the present specification.

According to Debye's theory of scattering, the size of the structure of uneven refractive index distributed inside the light scattering and guiding material may be represented in terms of a correlation distance a . The requirement of correlation distance $a \geq 0.06$ constitutes one practical criterion to exert clear emitting directivity in the light scattering and guiding material.

In addition to the light scattering light guide plate described above, a light guide plate having a large number of fine irregularities provided on a surface of a transparent plate to restrain total reflection is well known as the light guide plate with emitting directivity applicable to the surface light source device of side-light type. The irregularities may include numberless fine irregularities on the surface of the light guide plate itself or numberless fine particles fixed to a flat surface of a transparent plate with a light transmitting binder.

In the surface light source device of side-light type adopting the light guide plate with emitting directivity, extremely high luminance is obtained when an emitting surface is observed from a direction coincident with its directivity. However, a problem in this case is the fact that a main propagation direction, that is, "a preferential propagation direction" of an output flux from the emitting surface of the light guide plate with emitting directivity is largely deviated from a frontal direction of the emitting surface.

FIG. 1 is a graph illustrating the above fact, and angle characteristics of the intensity of output light in the surface

light source device of side-light type adopting the light guide plate with emitting directivity are plotted. The conditions of measurement in this graph are as schematically shown in FIG. 2. A light guide plate 1 used in the surface light source device to be measured is made of a light scattering and guiding material having a wedge-like sectional shape. This light scattering and guiding material has a matrix consisting of polymethyl methacrylate (PMMA having refractive index of 1.492), the numberless fine particles of refractive index different from that of the matrix are uniformly distributed in the matrix.

A silicone resin material (Tospearl 120: registered trademark/manufactured by Toshiba silicone Co., Ltd.) is distributed as the fine particles in the light guide plate 1 at a range of 0.03 wt %.

As shown in the drawing, the light guide plate 1 is sized to be 180 mm in depth as viewed from the side of an incidence surface 2, 135 mm in width, 2.5 mm in thickness on the side of the incidence surface 2, and 0.5 mm in thickness on the side of an end surface 7. A straight tube-like lamp L (a cold cathode type having a diameter ϕ of 2.4 mm) is disposed at a distance of 1.0 mm from the incidence surface 2 of the light guide plate 1. The lamp L is surrounded from the rear by a reflection sheet R consisting of silver foil in order to prevent light from being scattered and lost. A silver foil sheet is disposed as a reflector 3 along a back surface 6 of the light guide plate 1. A thin air layer (having a thickness of δ 1) is present between the silver foil sheet 3 and the back surface 6.

In FIG. 2, reference symbol M denotes a luminance meter (LS110 manufactured by Minolta, having a visual field angle of $\frac{1}{3}^\circ$ in measurement, and mounted with a close-up lens) used for measurement of luminance. In measurement with the luminance meter M, an observation of a central point P on the emitting surface 5 was made though a line of sight b at a distance of 203 mm from the central point. Then, the line of sight b was scanned by turning within a plane perpendicular to the lamp L. In the abscissa of the graph, a direction of the line of sight b is represented in terms of an output angle ϕ ($^\circ$). COS-corrected relative luminance values (%) to a peak value are plotted on the ordinate.

COS correction is made for compensating an emitting surface area corresponding to output light incident on the luminance meter for COS-functionally varying depending on the angle of the line of sight. COS correction is also applied to other graphs which will be described later.

As is read from the graph of FIG. 1, a sharp peak (a preferential propagation direction) is observed in a direction of an angle slightly lower than 80° . In view of such a fact, a surface light source device of side-light type adopting the light guide plate with emitting directivity will need to modify a preferential propagation direction of output light from the emitting surface. In particular, when this surface light source device is applied to a back lighting arrangement in a liquid crystal display, it is necessary to modify the preferential propagation direction to a frontal direction which is the most general direction of observation.

An element called a prism sheet has been conventionally used to modify the preferential propagation direction. As a known arrangement of the prism sheet, there are a prism sheet arrangement, in which a prism surface is faced inwards (is opposed to the emitting surface), and a prism sheet arrangement, in which a prism surface is faced outwards (turns its back on the emitting surface).

FIG. 3 is a sketch showing a basic arrangement of a surface light source device adopting the former arrange-

3

ment. This arrangement is provided by adding the prism sheet to the arrangement shown in FIG. 2 (an illustration of the conditions of measurement), and a reference numeral of each element is also used in common.

A prism sheet 4 is disposed on the outside of an emitting surface 5 of a light scattering light guide plate 1 with emitting directivity having a wedge-like sectional shape. The prism sheet 4 includes a light transmitting sheet having a surface provided with a large number of prism rows at fine pitches and a flat surface 4e. Each prism row is composed of a pair of slopes 4a, 4b.

A plastic material such as polycarbonate is usually used as a material of the prism sheet. As a matter of convenience, a distance between the prism sheet 4 and the emitting surface 5 and a pitch of prism rows are exaggerated in FIG. 3 and other drawings.

When the surface light source device is applied to a back lighting arrangement in a liquid crystal display, a well-known liquid crystal display panel is disposed on the further outside of the prism sheet 4. Since the light guide plate 1 has a wedge-like sectional shape, it is advantageous in improving a luminance level and ensuring uniformity in luminance. An action based on such a shape of the light guide plate is disclosed in Japanese Patent Laid-open No. 7-198956, for instance.

Light supplied from the lamp L to the light guide plate 1 is guided toward an end surface 7 on the thin side while being affected by a scattering action and a reflecting action in the light guide plate 1. In the process, illumination light is outputted little by little from the emitting surface 5. As described above, the output light from the emitting surface 5 of the light guide plate 1 with emitting directivity has a clear preferential propagation direction 5a. The preferential propagation direction 5a is inclined at an angle of about 60 to 80° with respect to a normal extending from the emitting surface 5, as illustrated in the graph of FIG. 1.

The output light from the emitting surface 5 in the preferential propagation direction 5a is introduced into the inside surfaces 4a, 4b of the prism sheet 4 and is outputted from the outside surface 4e to around a frontal direction. As a result, the preferential propagation direction is modified. A description of this modifying action will be given as follows with reference to FIG. 4.

FIG. 4 is a view for explaining the behavior of light in a section orthogonal to the lamp L in the arrangement shown in FIG. 3. In this case, "a direction orthogonal to the lamp L" means "a direction perpendicular to a running direction of the lamp L", that is, "a direction perpendicular to a running direction of the incidence surface 2". Hereinafter, it will be simply referred to as "orthogonal to the lamp". Similarly, "a direction parallel to a running direction of the lamp L", that is, "a direction parallel to a running direction of the incidence surface 2" will be referred to as "parallel to the lamp".

The prism sheet 4 is disposed inwardly along the emitting surface 5. This arrangement is briefly called an arrangement "with grooves inwards". Each prism unit forming the prism surfaces has an isosceles triangular section. Its apex angle is represented by $\phi 3$. A direction of incidence is given by an arrow L', and a preferential propagation direction of an output flux from the emitting surface 5 is represented in terms of an output angle $\phi 2$. As described above, the angle $\phi 2$ is generally sized to be in the range of about 60 to 80°.

The light guide plate 1 having PMMA matrix has refractive index of about 1.5, and an incidence angle $\phi 1$ of light propagating from the inside to the emitting surface 5 is sized

4

to be slightly lower than 40°. A beam defined by such an incidence angle $\phi 1$ and an output angle $\phi 2$ is represented by a typical beam B1. In general, the typical beam corresponds to a beam propagating in a preferential propagation direction.

After the typical beam B1 outputted from the emitting surface 5 makes a straight propagation through an air layer AR (having refractive index $n0$ of 1.0), this typical beam B1 is incident on the slope 4a of the prism sheet 4 at substantially right angles therewith and is affected by a refractive action to some extent. It is to be noted that the beam B1 is incident on the slope 4b opposite to the slope 4a at a relatively small rate.

The typical beam B1 further makes a substantially straight propagation through the prism sheet 4 up to its slope 4b, and is regularly reflected (totally reflected) by the slope 4b, resulting in being incident on the flat surface 4e of the prism sheet 4 from the inside. When the prism apex angle $\phi 3$ is appropriately designed according to the output angle $\phi 1$ and the refractive index $n2$ of the prism sheet 4 and so on, the incidence angle with respect to the flat surface 4e comes to be about 0°, and a beam 4f leading to around a frontal direction (at an angle $\phi 4$ of about 90°) is generated.

In this manner, the preferential propagation direction is completely modified to the frontal direction. In this arrangement, the prism sheet 4 functions as a deflecting element for an output flux represented by the typical beam B1, whereas it hardly functions as a converging element which narrows diffusion of the propagation direction of an output flux from the emitting surface 5. That is, a flux is sufficiently deflected whereas an action for converging the flux to improve a degree of parallelization in a propagation direction is hardly expected.

Although a propagation of light from a medium of low refractive index to a medium of high refractive index is applied to incidence of light on the prism sheet 4 through the air layer AR, the light is incident on the slope 4a at substantially right angles therewith as described above. Under these conditions, a converging action is hardly caused. The converging action is not caused even through a process of propagation in the prism sheet 4 or a process of reflection by the inside surface of the slope 4b.

In output of light from the flat surface 4e of the medium of high refractive index, diffusion of light occurs on the contrary. However, output of light at substantially right angles causes a low diffusing action from the reasons similar to those in case of incidence of light on the slope 4a.

An arrangement with prism surfaces facing outwards has been proposed in order to fulfill the converging action in the prism sheet 4. FIG. 5 is a sectional view for explaining the behavior of a typical beam in case of adopting the above arrangement.

Reference numerals 4c, 4d respectively denote slopes forming the outward prism surfaces, and 4g denotes an inward flat surface. The flat surface 4g is parallel to the emitting surface 5. This arrangement is briefly called an arrangement "with grooves outwards". A prism row serving as a prism unit of the prism sheet 4 having an apex angle $\phi 5$ has an isosceles triangular section. With respect to inclination angles $\phi 6$, $\phi 7$ of the slopes 4c, 4d, $\phi 6$ is sized to be equal to $\phi 7$.

Similarly to the case of FIG. 4, a direction of incidence is given by an arrow L', and a typical beam is represented by B2. The typical beam B2 is incident on the emitting surface 5 at an inside incidence angle $\phi 1$ slightly lower than 40°, and most of the beam is outputted to an air layer AR (having

refractive index n_0 of 1.0). An output angle ϕ_2 in this case is sized to be in the range of about 60 to 80°, as described above.

After the typical beam B2 outputted from the emitting surface 5 makes a straight propagation through the air layer AR, this typical beam B2 is obliquely incident on the flat surface 4g of the prism sheet 4, and is outputted from the surface 4c or 4d of the prism sheet 4 through refractive paths P1, P2 as shown in the drawing. When the prism apex angle ϕ_5 is appropriately designed according to the output angle ϕ_2 of the beam from the emitting surface 5 and the refractive index n_2 of the prism sheet 4, a propagation direction of output light 4f may be modified close to a frontal direction.

According to this arrangement, an action for converging a flux to a frontal direction may be fulfilled by (1) the fact that light is incident on the flat surface 4g parallel to the emitting surface 5 and (2) a function of the prism surfaces 4c, 4d as a kind of convex lens array.

The fact described in (1) may be generalized as follows.

If a light transmitting element having a flat surface is disposed such that the flat surface faces inwards and is parallel to the emitting surface 5, a flux obliquely incident on the flat surface is affected by a kind of converging action. A description of this fact will be simply given with reference to FIG. 6.

Referring to FIG. 6, a light transmitting element 10 having a flat surface 11 is disposed along an emitting surface 5 of a light guide plate 1 (having refractive index of 1.492) with emitting directivity as shown in the graph of FIG. 1. This light transmitting element 10 includes a flat plate (having refractive index of 1.492) made of PMMA, for instance. The flat surface 11 of the flat plate 10 is parallel to the emitting surface 5, and an air layer AR (having refractive index of 1.0) is present between the flat surface 11 and the emitting surface 5.

Now, with respect to a flux represented by a typical beam B10, let's pay attention to a "a partial flux" propagating through the air layer AR in the angle range of 20.0° around the preferential propagation direction. It is estimated from the result of actual measurement in FIG. 1 that such a partial beam is considered to represent most of an output flux from the emitting surface 5. Beams on both sides of the partial flux defined by this angle range are represented by B11, B12. An attempt to trace the beams B10, B11, B12 is made under the conditions of the above refractive index according to Snel's rule.

The results are shown in FIG. 6. The diffusion of a flux in the angle range of 20.1° in the propagation through the air layer AR is narrowed to that in the angle range of 6.9° through a process of refraction at the time of oblique incidence of light on the flat surface 11. In other words, the diffused state of the beams B10, B11, B12 (see reference symbols C to C") in the light guide plate 1 is recovered.

That is, when the flat surface of the light transmitting element formed on the surface of a medium having refractive index higher than that of the air layer AR is disposed in parallel to the emitting surface 5, this flat surface fulfills an action of recovering directivity once reduced due to an escape of light to the air layer AR.

A group of beams denoted by reference numerals C', S represents a situation of beams traced on the basis of a certain incidence point Q on the flat surface 11, and the converging action is more clearly understood from this situation.

While the arrangement "with grooves outwards" shown in FIG. 5 is excellent in utilization of such a converging action,

it has difficulty in obtaining a flux deflecting action, in comparison with the arrangement "with grooves inwards" shown in FIG. 4. That is, in the arrangement "with grooves outwards", it is not possible to utilize reflection by the inside surface such as the slope 4b in FIG. 4, and a flux is deflected only by a refracting action in both surfaces of the prism sheet.

That is, under the conditions of the refractive index (refractive index of about 1.5) of generally available materials for the prism sheet and the light guide plate, it is difficult to lead a flux to a frontal direction, even if the prism apex angle ϕ_5 is adjusted.

A graph of FIG. 7 shows the result of actual measurement illustrating this difficulty. With respect to the arrangement "with grooves inwards" and the arrangement "with grooves outwards", angle characteristics of output light intensity are given under the above conditions of measurement (see a description related to FIG. 2). In a graph I, angle characteristics of output light intensity are plotted when a prism sheet having a prism apex angle of 70° in the arrangement "with grooves outwards" is added to an arrangement corresponding to the graph of FIG. 1.

On the other hand, a graph II shows angle characteristics of output light intensity when a prism sheet having a prism apex angle of 66° in the arrangement "with grooves inwards" is added to the arrangement corresponding to the graph of FIG. 1. The ordinate is graduated so as to show relative luminance (%) on condition that a peak in the graph I is defined as 100.

As is read from a comparison between both the graphs, the arrangement "with grooves outwards" in the graph I is substantially excellent in function of convergence, while being inferior in function of deflection to a frontal direction, in comparison with the arrangement "with grooves inwards" in the graph II. A preferential propagation direction of illumination light is deviated from a frontal direction by 20° or more. Such a tendency is generally observed without being limited to the above case.

Therefore, two prism sheets in the arrangement "with grooves outwards" have been generally layered. A graph in FIG. 8 shows the result of actual measurement of angle characteristics of output light intensity when "two prism sheets in layers" are applied. The conditions of measurement are similar to those in FIG. 7.

A graph III shows angle characteristics of output light intensity when two prism sheets, i.e., a prism sheet having a prism apex angle of 66° and a prism sheet having a prism apex angle of 90° in the arrangement "with grooves outwards" are added in layers to the arrangement corresponding to the graph of FIG. 1. A graph II shows angle characteristics when the prism sheet having the prism apex angle of 66° as described in FIG. 7 is used in the arrangement with "grooves inwards". The ordinate is graduated so as to show relative luminance (%) on condition that a peak in the graph III is defined as 100.

As is read from both the graphs, two-layered arrangement "with grooves outwards" is not only substantially excellent in function of convergence, but also in function of deflection to a frontal direction, in comparison with the arrangement "with grooves inwards" in the graph II. In other words, the two-layered arrangement "with grooves outwards" eliminates a deficiency of the function of deflection in the single arrangement "with grooves outwards" shown in FIG. 7.

However, this method arises a problem caused by an overlap of fine grooves of the two prism sheets. That is, two prism sheets in layers have a tendency to generate moire

fringes. Further, a fixed phase relation between repetitive grooves of two prism sheets is required for obtaining higher efficiency of light utilization.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the problems in the prior art described above. That is, an object of the present invention is to provide a surface light source device of side-light type adopting a propagation direction characteristics modifier which fulfills a function of convergence to improve a degree of parallelization of a flux in a propagation direction, while deflecting an output flux from an emitting surface of a light guide plate with emitting directivity to a frontal direction.

The surface light source device of side-light type according to the present invention solves the above technical problems by disposing the propagation direction characteristics modifier along the emitting surface of the light guide plate with emitting directivity. This light guide plate preferably has a wedge-shaped section having a tendency to decrease a thickness according as a distance from a side end surface is increased. However, since the sectional shape of the light guide plate is not directly related to the essential characteristics of the present invention, the light guide plate may have a plate-like shape.

The propagation direction characteristics modifier used in the present invention has one-dimensional or two-dimensional array of a large number of projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to the emitting surface of the light guide plate. At least a part of a side portion of each projection element has a reflective deflection surface having a function of deflection to a frontal direction on the basis of reflection including total reflection. A reflection pattern means includes reflection portions formed in a distributed state so as to restrain a flux outputted with directivity from the emitting surface of the light guide plate from being incident on portions other than the flat regions of the projection elements.

A one-dimensional array of projection elements is typically formed by lining up a large number of ridge elements in parallel to a lamp. In this case, a reflective deflection surface having a function of deflection to a frontal direction on the basis of reflection including total reflection is provided on a side portion relatively distant from the lamp. The reflection portions of the reflection pattern means are distributed in the shape of stripes so as to restrain a flux outputted with directivity from the emitting surface of the light guide plate from being incident on portions other than the flat regions of the ridge elements.

When the projection elements are set in two-dimensional array, the shape of each projection element is selectively determined such that a reflective deflection surface having a function of two-dimensional deflection to a frontal direction on the basis of reflection including total reflection is further provided at least at a part of a side portion of each projection element. Each projection element of such a shape includes a pole-shaped projection, in particular, a square-pole-shaped projection, a conical-shaped projection (including a cylindrical projection).

In case of using the square-pole-shaped projection elements, each square-pole-shaped projection element is provided with three reflective deflection surfaces formed so as to have a function of two-dimensional deflection to a frontal direction on the basis of reflection including total reflection.

In case of using the conical-shaped projection elements, each conical-shaped projection element is provided with a peripheral surface having a function of two-dimensional deflection to a frontal direction on the basis of reflection including total reflection.

The reflection pattern means may specifically take the shape of a reflection pattern sheet disposed between the emitting surface of the light guide plate and the propagation direction characteristics modifier or reflection portions formed in a distributed state on the emitting surface of the light guide plate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing angle characteristics (in a section orthogonal to a lamp) of output light intensity when a light guide plate with emitting directivity is used in a surface light source device of side-light type;

FIG. 2 is a view for explaining conditions of measurement of output light intensity of a light guide plate;

FIG. 3 is a sketch showing a basic arrangement of a surface light source device of side-light type, in which a prism sheet is arranged inwards;

FIG. 4 is a view for explaining an action of a prism sheet arranged inwards;

FIG. 5 is a view for explaining an action of a prism sheet arranged outwards;

FIG. 6 is a view for explaining a general converging action caused by light obliquely incident on a flat surface;

FIG. 7 is a graph showing angle characteristics of output light intensity plotted under the conditions of measurement similar to those in FIG. 1 with respect to an arrangement "with grooves inwards" and an arrangement "with grooves outwards";

FIG. 8 is a graph showing a comparison for explaining an action when two prism sheets are layered in an arrangement "with grooves outwards";

FIG. 9 is a sketch showing an overall arrangement of an embodiment I;

FIG. 10 is an enlarged-scale sectional view showing the vicinity of an emitting surface of a light guide plate, a propagation direction characteristics modifier and a reflection pattern sheet, together with propagation paths of typical beams in relation to embodiment I to III;

FIG. 11 is a sketch showing an overall arrangement of the embodiment II;

FIG. 12 is a graph showing angle characteristics (in a section parallel to a lamp) of output light intensity when a light guide plate with emitting directivity is used in a surface light source device of side-light type;

FIG. 13 is a sketch showing an overall arrangement of the embodiment III;

FIG. 14 is a sketch showing an overall arrangement of an embodiment IV;

FIG. 15 is an enlarged-scale sectional view showing the vicinity of an emitting surface of a light guide plate, a propagation direction characteristics modifier, and a reflection pattern sheet, together with propagation paths of typical beams in relation to embodiments IV to VI;

FIG. 16 is a sketch showing an overall arrangement of the embodiment V;

FIG. 17 is a sketch showing an overall arrangement of the embodiment VI;

FIG. 18A is a sketch showing an overall arrangement of an embodiment VII together with an encircled portion shown on an enlarged scale in FIG. 18B;

FIG. 19A is a sketch showing an overall arrangement of an embodiment VIII together with an encircled portion shown on an enlarged scale in FIG. 19B;

FIG. 20A is a sketch showing an overall arrangement of an embodiment IX together with an encircled portion shown on an enlarged scale in FIG. 20B;

FIG. 21A is a sketch showing an overall arrangement of an embodiment X together with an encircled portion shown on an enlarged scale in FIG. 21B;

FIG. 22A is a sketch showing an overall arrangement of an embodiment XI together with an encircled portion shown on an enlarged scale in FIG. 22B; and

FIG. 23A is a sketch showing an overall arrangement of an embodiment XII together with an encircled portion shown on an enlarged scale in FIG. 23B.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention will now be described in detail with reference to embodiments I to XII according to the present invention. In a description of each embodiment, reference numerals are appropriately used in common. A repetitive description of the same elements, structure or function will be omitted according to circumstances. In particular, it is to be noted that a light guide plate used in each embodiment may be identical with that cited in FIGS. 1, 2 and 3 or the like.

A light guide plate 1 with emitting directivity used in each embodiment has a matrix consisting of polymethyl methacrylate (PMMA having refractive index of 1.492), and fine particles having refractive index different from that of the matrix, i.e., particles of different refractive index are uniformly distributed in the matrix. A silicone resin material (Tospearl 120: registered trademark/manufactured by Toshiba silicone Co., Ltd.) is used as the fine particles.

The silicone resin material is contained at a rate of 0.03 wt. %, for instance. It is to be noted that the rate of content of the particles of different refractive index is determined in view of a design. In general, the rate of content is set to be lower, according as an emitting surface is increased in size (depth).

The light guide plate 1 is specifically sized as described above. For instance, the light guide plate 1 is 180 mm in depth as viewed from the side of an incidence surface 2, 135 mm in width, 2.5 mm in thickness on the side of the incidence surface 2 and 0.5 mm in thickness on the side of an end surface 7. A straight tube-like lamp L (a cold cathode tube having a tube diameter 1 of 2.4 mm) is disposed as a light supply means at a distance of 1.0 mm from the incidence surface 2 of the light guide plate 1.

The lamp L is partially surrounded from the rear with a reflection sheet R consisting of silver foil in order to prevent light from being scattered and lost. A silver foil sheet is disposed as another reflector 3 along a back surface of the light guide plate 1.

Embodiment I

An overall arrangement is schematically shown in FIG. 9. In this embodiment, a propagation direction characteristics modifier 14 and a reflection pattern sheet 16 are disposed instead of the prism sheet 4 in the prior art shown in FIG. 3. The reflection pattern sheet 16 is disposed as a reflection pattern means on the inside of the propagation direction characteristics modifier 14.

A description will be given of a structure and a function of the propagation direction characteristics modifier 14 and

those of the reflection pattern sheet 16 with reference to FIG. 10. FIG. 10 is an enlarged-scale sectional view showing the vicinity of the emitting surface 5 of the light guide plate 1, the propagation direction characteristics modifier 14 and the reflection pattern sheet 16, together with propagation paths of typical beams.

Referring to FIGS. 9 and 10, the propagation direction characteristics modifier 14 is made of a transparent resin material (PMMA having refractive index of 1.492). The propagation direction characteristics modifier 14 includes a large number of ridges 14c as projection elements which form on-dimensional array. A distal end of each ridge 14c has a flat region 14g. each flat region 14g has a parallel relation to the emitting surface 5, and functions as an input surface which receives output light from the emitting surface 5. Between two side surfaces 14a, 14b of each ridge 14c, the side surface 14b distant from the incidence surface 2 functions as a total reflection surface which deflects light introduced into the propagation direction characteristics modifier 14 to a frontal direction in a section orthogonal to the lamp.

An inclination angle of the reflective deflection surface 14b is designed to be fit for such a function of deflection. Although an inclination angle of the other side surface 14a is arbitrarily determined in general, this inclination angle is preferably designed such that a distance between the flat regions 14g may be sized as small as possible.

The reflection pattern sheet 16 disposed inside the propagation direction characteristics modifier 14 is also made of a transparent resin material (PMMA having refractive index of 1.492), and reflection portions 16r are distributed in a stripe pattern on one surface (an inside surface in this embodiment). A portion between one reflection portion 16r and its adjacent reflection portion 16r is provided as a window portion 16w. The reflection portions 16r may preferably take the shape of a layer or film consisting of Ag or Al having regular reflecting properties.

A pattern of light and shade stripes observed on the outside surface of the reflection pattern sheet 16 in FIG. 9 represents light and shade portions formed by an action which will be described later. This stripe pattern is not equivalent to a pattern of stripes of the reflection portions 16r and the window portions 16w themselves. However, when the reflection portions 16r are formed on the outside surface of the reflection pattern sheet 16, it is to be noted that the stripes of light and shade portions shown in FIG. 9 represent light and shade portions defined by the reflection portions 16r.

A cycle of formation of the reflection portions 16r is designed to be equal with a cycle of formation of the projection elements 14c of the propagation direction characteristics modifier 14. A relatively positional relation between the size (stripe width) of each reflection portion 16r and each projection element (ridge) 14c is designed so as to block light from being incident on a V-shaped notch portion between the flat regions 14g without obstructing light incident on each flat region 14g.

A process of deflection of a flux to a frontal direction and convergence in this embodiment is as follows.

(1) A flux having clear directivity is outputted from the emitting surface 5 of the light guide plate 1 with emitting directivity. As described above, the preferential propagation direction of this flux is inclined at an angle of about 60 to 80° with respect to a normal extending from the emitting surface 5. In this case, an output flux is represented by beams C1, C2 outputted at an angle of 70° to the normal by taking the mean between the above inclination angles. However, this flux is diffused to some extent in a propagation direction (See FIG. 6).

(2) The output flux is led to the reflection pattern sheet 16, and is incident on the reflection portions 16r or the window portions 16w. Each window portion 16w is formed as a flat surface having no reflection portion 16r. Most of the flux (represented by C1) incident on the window portions 16w is refracted according to Snel's rule of refraction, and makes a propagation into the reflection pattern sheet 16.

On the other hand, a flux (represented by C2) incident on the reflection portions 16r is reflected toward the emitting surface 5. The reflected light or a small quantity of light reflected from the window portions 16w is given an opportunity of incidence on the reflection pattern sheet 16 again through a process including reflection by the emitting surface 5, incidence on the light guide plate 1 again, output from the emitting surface 5 again and so on. In this manner, the reflected light is utilized through a recycling process.

(3) The flux having intruded into the reflection pattern sheet 16 directly or through the recycling process is outputted from the flat outside surface 16g to the air layer AR again. In this case, refraction occurs according to Snel's rule. However, since a phenomenon occurring in 16w and that occurring in 16g are canceled with each other, it may be considered that a direction of the flux (C1) and its diffusion do not vary before and after the transmission of flux through the reflection pattern sheet 16.

As described above, the light and shade portions corresponding to the stripe pattern of the reflection portions 16r are formed on the outside surface 16g of the reflection pattern sheet 16.

(4) The flux (represented by C1) transmitted through the reflection pattern sheet 16 is obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14. In other words, a structure and an arrangement of the propagation direction characteristics modifier 14 and those of the reflection pattern sheet 15 are designed such that a path of the flux transmitted through the reflection pattern sheet 18 and a position and a size of each flat region 14g are matched with each other.

When the light is obliquely incident on the flat regions 14g, a degree of parallelization of the flux in the propagation direction is improved by the converging action which has been described with reference to FIG. 6. The light is blocked by the reflection pattern sheet 16 from being incident on the notch portions (uneffective areas) between the flat regions 14g.

(5) The flux (represented by C1) obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14 is totally reflected by the total reflective deflection side surfaces 14b of the projection elements 14c. In the total reflection, it is a matter of course that the degree of parallelization of the flux improved by the incidence on the flat regions 14g is not degraded.

An inclination angle of each total reflective deflection side surface 14b is designed such that a flux is deflected to around a frontal direction due to the total reflection. In this case, an inclination angle $\alpha 1$ of 70.5° is given on the assumption that this inclination angle is calculated as an optimum angle on condition that the typical beam C1 (at an output angle of 70° from the emitting surface 5) is taken as an instance, and the propagation direction characteristics modifier 14 and the reflection pattern sheet 16 respectively have refractive index of 1.492.

The optimum inclination angle of each reflective deflection surface 14b varies to some extent according to conditions of the output angle (substantially depending on the refractive index of the light guide plate 1) of the beam from

the emitting surface 5, and the refractive index of the propagation direction characteristics modifier 14 and that of the reflection pattern sheet 16. The materials practically used for the light guide plate 1, the propagation direction characteristics modifier 14 and the reflection pattern sheet 16 have refractive index in the range of about 1.49 to 1.6. $\alpha 1$ is practically in the range of $67^\circ \leq \alpha 1 \leq 75^\circ$ when calculated in view of the above refractive index.

Although an inclination angle $\alpha 2$ of the other surface 14a has no absolute limitation, it is not preferable from points of view in technique of manufacture and mechanical strength that $\alpha 2$ is largely lower than $\alpha 1$. In this case, it may be that light reflected by the reflective deflection surfaces 14b will be reflected again.

On the other hand, when $\alpha 2$ largely exceeds 90° , a problem arises in reduction of the rate of occupation of the flat regions 14g. In consideration of these facts, $\alpha 2$ is practically in the range of $64^\circ \leq \alpha 2 \leq 115^\circ$. It is preferable in the range of $90^\circ \leq \alpha 2 \leq 110^\circ$. In particular, an inclination angle $\alpha 2$ of about 90° is advantageous in facilitating a manufacture process and in providing a high rate of occupation of the flat regions 14g.

(6) The flux deflected to around the frontal direction due to the total reflection by each reflective deflection surface 14b is incident on the flat outside surface 14h of the propagation direction characteristics modifier 14 at substantially right angles therewith, and is radiated as an illumination flux to the outside air layer AR. This process corresponds to a propagation of a flux from a high reflective index medium to a low refractive index medium. However, since the flux is incident on the outside surface 14h at substantially right angles therewith, diffusion of the flux (degradation of the degree of parallelization) hardly occurs. Consequently, the deflection of the flux is achieved together with the improvement in the degree of parallelization due to transmission of the flux through the flat propagation direction characteristics modifier 16.

According to a modification of this embodiment I, the reflection portions 16r may be formed on the outside surface of the reflection pattern sheet 16. An action in this case is substantially similar to that in the above-described embodiment I, except that reflection occurs on the outside surface of the reflection pattern sheet 16, instead of the inside surface thereof.

Embodiment II

Referring to FIG. 11, a structure similar to that of the embodiment I is applied to this embodiment. However, a prismatic groove array 15 lined up in a direction orthogonal to the lamp is formed on an outside surface of a propagation direction characteristics modifier 14. A detailed description of a structure and a function common to those in the embodiment I will be omitted.

According to this embodiment, frontal directivity is improved in a section parallel to the lamp, since the prismatic groove array 15 lined up in the direction orthogonal to the lamp is formed on the outside surface of the propagation direction characteristics modifier 14.

Such a technical means is effective, since output light from an emitting surface of a light guide plate 1 with emitting directivity shows gentle directivity to a frontal direction in a section parallel to the lamp, and there is room for improvement in directivity.

FIG. 12 is a graph similar to that in FIG. 1 and illustrating the above fact. A substance (a surface light source device of side-light type) to be measured to provide this graph is

13

identical with that to provide the graph in FIG. 1. However, a section for scanning by turning a line of sight of a luminance meter is perpendicular to the substance to be measured shown in FIG. 2. That is, the luminance meter is scanned by turning in a section which is parallel to the lamp and passes through a central point P (See FIG. 2) of the emitting surface on condition that the line of sight of the luminance meter always passes through the central point P. A measured luminance value is plotted on the ordinate after having been calculated in terms of a relative luminance value (%) to a peak value.

As read from the graph in FIG. 1, it may be considered that a considerable quantity of light is outputted even in a direction largely deviated from a frontal direction (0°).

An optical action of the prismatic groove array 15 formed on the outside surface of the propagation direction characteristics modifier 14 is basically equal to that of the prism surfaces 4c, 4d of the prism sheet 4 which has been described in FIG. 5. However, the prismatic groove array 15 effectively fulfills an action of deflection and convergence in a direction perpendicular to a direction (a direction orthogonal to the lamp) of the prismatic groove array 15, that is, in a section parallel to the lamp.

Accordingly, brightness of the surface light source device as viewed from a frontal direction is further improved by forming such a prismatic groove array 15 on the outside surface of the propagation direction characteristics modifier 14. An apex angle of each prism element forming the prismatic groove array 15 may be preferably sized to be in the range of about 90° to 110° , particularly about 100° .

Embodiment III

Referring to FIG. 13, a cylindrical lens array, instead of the prismatic groove array, is formed on an outside surface of a propagation direction characteristics modifier 14. As a matter of course, the cylindrical lens array 15 is oriented in a direction orthogonal to the lamp. It is not too much to say that such a cylindrical lens array 15 fulfills an action of deflection and convergence similar to that of the prismatic groove array in the embodiment II, and improves brightness of a surface light source device as viewed from a frontal direction.

Embodiment IV

Referring to FIG. 14, the reflection pattern sheet 16 in the embodiment I is replaced with a reflection pattern formed on an emitting surface 5 of a light guide plate 1.

A structure and a function of the reflection pattern formed on the light guide plate 1 will be described with reference to FIG. 15. FIG. 15 is an enlarged-scale sectional view showing the vicinity of the emitting surface 5 of the light guide plate 1 and a propagation direction characteristics modifier 14 in the form similar to that shown in FIG. 10, together with propagation paths of typical beams.

Referring to FIGS. 14 and 15, the propagation direction characteristics modifier 14 is basically similar to that shown in FIG. 10. Therefore, a repetitive detailed description of its structure and function will be omitted.

The reflection pattern formed on the emitting surface 5 of the light guide plate 1 includes a large number of reflection portions 1r. These reflection portions 1r are distributed so as to form the stripe pattern as shown in FIG. 14. The reflection portions 1r may preferably take the shade of a layer or film consisting of Ag or Al having regular reflecting properties. A cycle of formation of the reflection portions 1r

14

is designed to be equal with a cycle of formation of the projection elements 14c of the propagation direction characteristics modifier 14.

A relatively positional relation between the size (stripe width) of each reflection portion 1r and each projection element (ridge) 14c is designed to block light from being incident on a V-shaped notch portion between the flat regions 14g without obstructing light incident on each flat region 14g. Such reflection portions 1r fulfill a function similar to that of the reflection portions 16r of the reflection pattern sheet 16 used in the embodiments I to III.

A process of deflection of a flux to a frontal direction and convergence in this embodiment is as follows.

(1) A flux having clear directivity is outputted from window portions 1w, that is, portions having no reflection portions 1r, of the emitting surface 5 of the light guide plate 1 with emitting directivity. The preferential propagation direction of such a flux is inclined at an angle of about 60° to 80° with respect to a normal extending from the emitting surface 5. In this case, an output flux is represented by a beam C01 outputted at an angle of 70° with respect to the normal described above by taking the mean between the above inclination angles. However, this flux is diffused to some extent in a propagation direction (see FIG. 6).

On the other hand, a flux (represented by C02) incident on the reflection portions 1r within the light guide plate 1 is returned to the light guide plate 1. This reflected light is given an opportunity of output of light from the window portions 1w again through a process including scattering inside the light guide plate 1 and reflection by the back surface. In this manner, light reflected by the reflection portions 1r is utilized through a recycling process.

(2) The flux (represented by C01) having escaped from the window portions 1w into the air layer AR directly or through the above recycling process is obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14. In other words, an arrangement of the propagation direction characteristics modifier 14 and that of the reflection portions 1r are designed such that a path of the flux having escaped from the window portions 1w and a position and a size of the flat regions 14g are matched with each other.

When the light is obliquely incident on the flat regions 14g, a degree of parallelization of a flux in a propagation direction is improved by the converging action which has been described with reference to FIG. 6. It is to be noted that light is blocked by the reflection portions 1r from being incident on notch portions (uneffective area) between the flat regions 14g.

(3) The flux (represented by C01) obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14 is totally reflected by one reflective deflection surface 14b of each projection element 14c. There is no possibility that the degree of parallelization of the flux improved by the light incident on the flat regions 14g is degraded due to such total reflection. As described in the embodiment I, an inclination angle of each reflective deflection surface 14b is designed such that a flux is deflected to around a frontal direction due to the total reflection.

In this case, an inclination angle $\alpha 1$ of 70.5° is given as an optimum angle calculated on condition that the typical beam C01 (at an output angle of 70° from the emitting surface 5) is taken as an instance and the propagation direction characteristics modifier 14 has refractive index of 1.492.

The optimum inclination angle of the reflective deflection surface 14b varies to some extent according to the condi-

15

tions of the output angle (substantially depending on the refractive index of the light guide plate 1) from the emitting surface 5 and the refractive index of the propagation direction characteristics modifier 14. As described above, the materials practically used for the light guide plate 1 and the propagation direction characteristics modifier 14 have refractive index in the range of about 1.49 to 1.6. $\alpha 1$ is practically in the range of $65^\circ \leq \alpha 1 \leq 75^\circ$ when calculated on assumption of the above fact.

An inclination angle $\alpha 2$ of the other surface 14a has no absolute limitation. As described above, $\alpha 2$ is practically in the range of $65^\circ \leq \alpha 2 \leq 115^\circ$, preferably $90^\circ \leq \alpha 2 \leq 110^\circ$. Further, similarly to the case in the embodiments I to III, an inclination angle $\alpha 2$ of about 90° is effective in facilitating a manufacture process and in providing a high rate of occupation of the flat regions 14g.

(4) The flux deflected to around the frontal direction due to the total reflection of the reflective deflection surfaces 14b is incident on the flat outside surface 14h of the propagation direction characteristics modifier 14 at substantially right angle therewith, and is radiated as an illumination flux to the outside air layer AR. This process corresponds to a propagation of a flux from a high refractive index medium to a low refractive index medium.

Since the light is incident on the outside surface 14h at substantially right angles therewith, diffusion of the flux (degradation of the degree of parallelization) hardly occurs. Consequently, the deflection of the flux is achieved together with the improvement in the degree of parallelization due to transmission of light through the flat propagation direction characteristics modifier 14.

Embodiment V

Referring to FIG. 16, a structure basically similar to that in the embodiment IV is applied to this embodiment. However, a prismatic groove array 15 lined up in a direction orthogonal to the lamp is formed on the outside surface of the propagation direction characteristics modifier 14. It is not too much to say that an action of the prismatic groove array 15 formed on the outside surface of the propagation direction characteristics modifier 14 is similar to that described in the embodiment II.

Brightness of a surface light source device as viewed from a frontal direction is further improved by forming the prismatic groove array 15 on the outside surface of the propagation direction characteristics modifier 14. An apex angle of each prism element forming the prismatic groove array 15 is preferably sized to be in the range of about 90° to 110° , particularly about 100° , similarly to the case of the embodiment II.

Embodiment VI

Referring to FIG. 17, a cylindrical lens array, instead of the prismatic groove array, is formed on the outside surface of the propagation direction characteristics modifier in the embodiment V. The cylindrical lens array 15 is oriented in a direction orthogonal to the lamp. It is not too much to say that such a cylindrical lens array 15 fulfills an action of deflection and convergence similar to that in the embodiment III and improves brightness of a surface light source device as viewed from a frontal direction.

The above embodiments I to IV include the propagation direction characteristics modifier formed by one-dimensionally arraying a large number of projection elements. On the other hand, embodiments VII to XII which

16

will be described later include a propagation direction characteristics modifier formed by two-dimensionally arraying a large number of projection elements.

A two dimensional array of projection elements such as pole-shaped projection elements each having a distal end provided with a flat region may be formed in order to two-dimensionally array a large number of projection elements.

An object to form a two-dimensional array of projection elements is to carry out a deflection to a frontal direction and a convergence not only in a section orthogonal to the lamp but also in a section parallel to the lamp and to further two-dimensionally improve the degree of parallelization of an illumination flux.

That is, the two-dimensional array of projection elements is designed to prevent an illumination flux from being diffused in a lateral direction as viewed from the lamp side for radiation, similarly to the prismatic groove or cylindrical lens used in the embodiments II, III, V and VI.

Accordingly, a function of preventing an illumination flux from being diffused in a lateral direction may be multiply enhanced by using the two-dimensional array of projection elements and the prism groove or the cylindrical lens in combination. Embodiments VII, VIII, X and XI show a specific structure including the two-dimensional array of projection elements and the prism groove or the cylindrical lens in combination.

Embodiment VII

This embodiment is equivalent to a structure in which the propagation direction characteristics modifier and the reflection pattern sheet in the embodiment I are modified from one-dimensional type to two-dimensional type. That is, as shown an overall arrangement in FIG. 18A together with an encircled portion on an enlarged scale in FIG. 18B, a propagation direction characteristics modifier 14 and a reflection pattern sheet 16 are disposed along a light guide plate with emitting directivity. This arrangement is similar to that in the embodiments I to III. Further, materials used for the propagation direction characteristics modifier 14 and the reflection pattern sheet 16 may be similar to those in the embodiments I to III.

However, the propagation direction characteristics modifier 14 and the reflection pattern sheet 16 are partially different in structure and function from those in the embodiments I to III. A description will now be given of this difference. The propagation direction characteristics modifier 14 made of a transparent resin material such as PMMA, for instance, includes a large number of square-pole-shaped projections 14c as projection elements forming a two-dimensional array.

A distal end of each square-pole-shaped projection 14c has a flat region 14a. Each flat region 14g has a parallel reflection to an emitting surface 5 and functions as an input surface which receives output light from the emitting surface 5, similarly to the case of one-dimensional array.

Among four side surfaces of each square-pole-shaped projection 14c, one side surface 14b distant from an incidence surface 2 functions as a total reflection surface which deflects light introduced in the propagation direction characteristics modifier 14 to a frontal direction in a section orthogonal to the lamp. That is, it fulfills a function similar to that of the reflective deflection surface 14b of the propagation direction characteristics modifier in one-dimensional array (embodiments I to IV).

Accordingly, an issue on size of an inclination angle of the reflective deflection surface in the description related to the

embodiment I is also applied to this embodiment. That is, an inclination angle of the reflective deflection surface 14b is sized to be in the range of about 67 to 75° under practical conditions.

An inclination angle of the side surface 14a opposed to the reflective deflection surface 14b is sized to be generally in the range of 65 to 115°, preferably in the range of 90 to 110°, particularly about 90°, for the reasons similar to those in the case of the embodiment I.

Other two side surfaces 14e, 14f function as reflection surfaces which deflect light introduced in the propagation direction characteristics modifier 14 to a frontal direction in a section parallel to the lamp. That is, the side surfaces 14e, 14f are different from the side surface 14b in effective direction of a function (perpendicular direction), but fulfills a function similar to that of the reflective deflection surface 14b. However, since a flux in a propagation direction is considerably diffused in a section parallel to the lamp, the side surfaces 14e, 14f cause considerable reflection which is not so much total reflection as the case of the reflective deflection surface 14b (See the graphs of FIGS. 1 and 10).

However, since there is no essential difference between the reflective reflection surfaces in function of reflective deflection itself, an inclination angle of the reflective deflection surface 14a may be sized on the basis of an inclination angle of the reflective deflection surface 14b. Accordingly, the inclination angle of the reflective deflection surface 14a may be sized to be in the range of 67 to 75°. Inclination angles of three reflecting deflection surfaces 14b, 14e, 14f may be designed to be equal with one another within the above range.

The reflection pattern sheet 16 is made of a transparent resin material such as PMMA, for instance, and is disposed on the inside of the propagation direction characteristics modifier 14. Reflection portions 16r are formed in a distributed state on one surface (an outside surface in this embodiment) according to a grid pattern. The reflection portions 16r may preferably take the shape of a layer or film consisting of Ag or Al having regular reflecting properties. A surface region having no reflection portion 16r is provided as a window portion 16w.

When the reflection portions 16r are formed on the inside surface of the reflection pattern sheet 16, it is to be noted that a pattern of light and shade portions shown in FIGS. 18A and 18B is not a pattern of the reflection portions and the window portions themselves and represents a pattern of light and shade portions appeared on the outside surface of the reflection pattern sheet 16.

The reflection pattern sheet 16 is provided to block output light from the emitting surface 5 of the light guide plate 1 from being incident on a notch portion (uneffective area) other than the flat region 14g of each projection element. Accordingly, a cycle of formation of the window portions 16w is designed to be equal with a cycle of formation of the projection elements 14c of the propagation direction characteristics modifier 14, similarly to the case of the embodiments I to III.

A two-dimensionally relatively positional relation between the size (grid width) of each reflection portion 16r and each projection element (square-pole-shaped projection) 14c is designed to block light from being incident on the notch portion between the flat regions 14g without obstructing light incident on each flat region 14g.

In this embodiment, a process of deflection of a flux to a frontal direction and convergence is two-dimensionally achieved as follows.

(1) A flux having clear directivity is outputted from the emitting surface 5 of the light guide plate 1 with emitting directivity. As described above, the preferential propagation direction of this flux is generally inclined at an angle of about 60 to 80° with respect to a normal extending from the emitting surface 5. The flux is diffused to some extent in a propagation direction with respect to both of a section orthogonal to the lamp and a section parallel to the lamp. In general, diffusion of the flux in a propagation direction occurs more largely with respect to the latter section (See FIGS. 1, 6 and 12).

(2) The output flux is incident on the reflection portions 16r or the window portions 16w after having been transmitted through the inside of the reflection pattern sheet 16 (or directly incident when the reflection portions 16 are formed on the inside of the reflection pattern sheet 15). The flux incident on the reflection portions 16r is reflected inwards. This reflected light and a small quantity of light reflected from the window portions 16w are given an opportunity of incidence on the window portions 16w again through a process including reflection by the inside surface of the reflection pattern sheet 16, reflection by the emitting surface 5, incidence on the light guide plate 1 again and output from the emitting surface 5 again. In this manner, the reflected light is utilized through a recycling process.

(3) The flux having been transmitted through the reflection pattern sheet 16 directly or through the above recycling process is obliquely incident on the flat region 14g of each square-pole-shaped projection 14c. In other words, a structure and arrangement of the propagation direction characteristics modifier 14 and those of the reflection pattern sheet 16 are designed such that a path of a flux transmitted through the reflection pattern sheet 16 and a position and a size of each flat region 14g are two-dimensionally matched with each other.

When the light is obliquely incident on the flat regions 14g, the degree of parallelization of the flux in a propagation direction is improved by the converging action which has been described with reference to FIG. 6. Incidentally, light is blocked by the reflection pattern sheet 16 from being incident on a notched portion (uneffective area) between the flat regions 14g.

(4) The flux obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14 (it is to be noted that this flux is two-dimensionally diffused in a propagation direction) is reflected by three reflective deflection surfaces 14b, 14e, 14f of the square-pole-shaped element 14c and is deflected to around a frontal direction. In reflection by the reflective deflection surface 14b, the flux is substantially totally reflected. The degree of parallelization of the flux is not degraded due to the reflection by these reflective deflection surfaces 14b, 14e, 14f.

(5) The flux deflected to around the frontal direction is incident on the outside surface of the propagation direction characteristics modifier 14 at substantially right angles therewith, and is radiated as an illumination flux to the outside air layer. This process corresponds to a propagation of a flux from a high refractive index medium to a low refractive index medium. However, since light is incident on the outside surface at substantially right angles therewith in a two-dimensional sense, diffusion of the flux (degradation of the degree of parallelization) hardly occurs not only in a section orthogonal to the lamp but also in a section parallel to the lamp. Consequently, in this embodiment, the deflection of the flux and the improvement in the degree of parallelization are two-dimensionally achieved.

FIGS. 19A through 20B show overall arrangements of these embodiments together with an encircled portions shown on an enlarged scale in FIGS. 19B and 20B, respectively. According to each embodiment, a prismatic groove array 15 (embodiment VIII) or a cylindrical lens 15 (embodiment IX) lined up in a direction orthogonal to the lamp is formed on an outside surface of a propagation direction characteristics modifier 14, while a structure basically similar to that in the embodiment VII is applied to this embodiment. A repetitive description of a structure and a function common to those in the embodiment VII will be omitted.

The prismatic groove array 15 or the cylindrical lens 15 is basically similar in structure and function to that used in the embodiment II or III. However, since the projection elements of the propagation direction characteristics modifier 14 are two-dimensionally arrayed differently from the embodiments II and III, it is to be noted that a function of preventing an illumination flux from being diffused in a lateral direction is multiply enhanced.

Embodiment X

According to this embodiment, the square-pole-shaped projection elements of the propagation direction characteristics modifier in the embodiment VII are replaced with conical-shaped projection elements. A pattern of reflection portions of a reflection pattern sheet is modified according to this replacement. Hereinafter, "conical-shaped projection elements" include cylindrical projection elements.

That is, as shown in an overall arrangement in FIG. 21A together with an encircled portion on an enlarged scale in FIG. 21B, a propagation direction characteristics modifier 14 in this embodiment includes a large number of conical-shaped projections 14c as projection elements forming a two-dimensional array. A distal end of each conical-shaped projection 14c has a flat region 14g. Each flat region 14g has a parallel relation to an emitting surface 5, and functions as an input surface which receives output light from the emitting surface 5, similarly to other embodiments.

In FIGS. 21A to 23B, it is to be noted that the propagation direction characteristics modifier is drawn as being slightly inclined to the emitting surface 5 so as to show the flat surface 14g.

A peripheral surface 14s of each conical-shaped projection 14c corresponds to a surface formed by smoothly curving of each of four surfaces 14a, 14b, 14e, 14f of each square-pole-shaped projection in the embodiments VII to IX. Its function continuously varies depending on a position in a peripheral direction. A peripheral surface portion on a relatively distant side (a side behind the rear) as viewed from the lamp L fulfills a function of deflection to a frontal direction in a section orthogonal to the lamp (assumes the role similar to that of the side surface 14b). This deflection is mainly carried out due to the total reflection.

When getting nearer to a peripheral surface portion on both the right sides as viewed from the lamp L, a function of deflection to a frontal direction in a section orthogonal to the lamp is reduced more than that in the peripheral surface portion on the relatively distant side described above, while a function of deflection to a frontal direction in a section parallel to the lamp is increased (assumes the role similar to that of the side surfaces 14e, 14f).

Then, when getting nearer to a peripheral surface portion on the close side (on this side) as viewed from the lamp L,

the function of deflection in any section is rapidly made ineffective (assumes the role similar to that of the side surface 14a).

In consideration of a distribution of functions as described above, an inclination angle of a ridge line on the most distant side as viewed from the lamp L is preferably sized to be in the range of about 67 to 75° on the analogy of a case of using the square-pole shaped projections described above.

An inclination angle of a ridge line on the closest side as viewed from the lamp is preferably sized to be in the range of about 65 to 115°, particularly in the range of 90 to 110°, further limited to about 90°.

The reflection pattern sheet 16 is made of a transparent resin material such as PMMA, for instance, and is disposed on the inside of a propagation direction characteristics modifier 14. Reflection portions 16r are formed in a distributed state on one surface (an outside surface in this embodiment) according to a grid pattern of round bores.

Portions having no reflection portion 16r are provided as window portions 16w of a substantially circular or elliptical shape. The reflection portions 16r preferably take the shape of a layer or film consisting of Ag or Al having regular reflecting properties.

When the reflection portions 16r are formed on the inside surface of the reflection pattern sheet 16, a pattern of light and shade portions shown in FIGS. 21A and 21B is not a pattern of the reflection portions and the window portions themselves, and represents a pattern of light and shade portions appeared on the outside surface of the reflection pattern sheet 16.

The reflection pattern sheet 16 is provided to block output light from the emitting surface 5 of the light guide plate 1 from being incident on a notch portion (uneffectively area) other than the flat region 14g of each projection element. Accordingly, a cycle of formation of the window portions 16w is designed to be equal with a cycle of formation of the projection elements 14c of the propagation direction characteristics modifier 14, similarly to the case of the other embodiments.

A two-dimensionally relatively positional relation between the size of each reflection portion 16r and each projection element (conical-shaped projection) 14c is designed to block light from being incident on the notch portion between the flat regions 14g without obstructing light incident on the flat regions 14g.

In this embodiment, a process of deflection of a flux to a frontal direction and convergence is two-dimensionally achieved as follows.

(1) A flux having clear directivity is outputted from an emitting surface of a light guide plate 1 with emitting directivity at an angle of about 60 to 80° with respect to a normal extending from the emitting surface. This flux is diffused to some extent in a propagation direction with respect to both of a section orthogonal to the lamp and a section parallel to the lamp. As described above, diffusion of the flux with respect to the latter section largely occurs in general.

(2) The output flux is incident on the reflection portions 16r or the window portions 16w after having been transmitted through the reflection pattern sheet 16 (directly incident when the reflection portions 16r are formed on the inside of the reflection pattern sheet 16). The flux incident on the reflection portions 16r is reflected inwards.

This reflected light and a small quantity of light reflected from the window portions 16w are given an opportunity of

21

incidence on the window portions 16w again through a process including reflection by the inside surface of the reflection pattern sheet 16, reflection by the emitting surface, incidence on the light guide plate 1 again and output from the emitting surface 5 again. In this manner, the reflected light is utilized through a recycling process.

(3) The flux transmitted through the reflection pattern sheet 16 directly or through the above recycling process is obliquely incident on the flat region 14g of each conical-shaped projection 14c. When the flux is obliquely incident on the flat regions 14g, the degree of parallelization of the flux in a propagation direction is improved. The flux is blocked by the reflection pattern sheet 16 from being incident on a notch portion (uneffective area) between the flat regions 14g.

(4) The flux obliquely incident on the flat regions 14g of the propagation direction characteristics modifier 14 (it is to be noted that this flux is two-dimensionally diffused in a propagation direction) is reflected by any portion of the peripheral surface 14s of each conical-shaped projection 14c, is subsequently reflected according to the distribution of functions described above (a considerable portion is totally reflected), and is then deflected to around a frontal direction. The degradation of the degree of parallelization of the flux due to this reflection hardly occurs.

(5) The flux deflected to around the frontal direction is incident on the outside surface of the propagation direction characteristics modifier 14 at substantially right angles therewith, and is radiated as an illumination flux to an outside air layer. This process corresponds to a propagation of a flux from a high refractive index medium to a low refractive index medium. However, since the flux is incident on the outside surface at substantially right angles therewith in a two-dimensional sense, diffusion of the flux (degradation of the degree of parallelization) hardly occurs not only in a section orthogonal to the lamp but also in a section parallel to the lamp. Consequently, in this embodiment, the deflection of the flux and the improvement in the degree of parallelization are two-dimensionally achieved.

Embodiments XI and XII

FIGS. 22A through 23A show overall arrangements of these embodiments together with an encircled portions shown on an enlarged scale in FIGS. 22B and 23B, respectively. According to these embodiments, a prismatic groove array 15 (embodiment XI) or a cylindrical lens 15 (embodiment XII) lined up in a direction orthogonal to the lamp is formed on an outside surface of a propagation direction characteristics modifier 14, while a structure basically similar to that in the embodiment X is applied to this embodiment. A repetitive description of a structure and a function common to those in the embodiment XII will be omitted.

The prismatic groove array 15 or the cylindrical lens 15 is basically similar in structure and function to that used in the embodiments II, III, VIII and IX. Since projection elements (conical-shaped projections) of the propagation direction characteristics modifier 14 in these embodiments are two-dimensionally arrayed, similarly to those in the embodiments VIII and IX, it is to be noted that a function of preventing an illumination flux from being diffused in a lateral direction is multiply enhanced.

Although twelve enhancements have been described above, the present invention is not limited to these embodiments. For instance, the present invention may be modified as follows.

22

(1) The light guide plate 1 with emitting directivity may not be made of the light scattering and guiding material. For instance, it may be made of a transparent optical material having a surface provided with fine irregularities for restraining the total reflection.

(2) The reflection pattern sheet used in the embodiments X to XII may be replaced with a reflection pattern formed on the emitting surface of the light guide plate, similarly to the embodiments IV to VI.

(3) The square-pole-shaped projections in the embodiments VII to XII may taken the shape of a square pyramid, instead of a normal square pole shape. That is, "the square-pole-shaped projections" in the present invention include square pyramid-shaped projections.

The pole-shaped projections in the embodiments X to XII may take the shape other than a conical pole and a square pole, as long as these projections fulfill a function of deflection to a frontal direction due to the total reflection at least in a section orthogonal to the lamp. The deflection may not be always based on the total reflection.

The shape of the pole-shaped projections includes an elliptical conical shape flat in a direction parallel to the lamp, a quasi-square pole shape expanded to the lateral side as viewed from the lamp side, and a polygonal pole shape (including a polygonal pyramidal shape) such as a pentagonal pole and a hexagonal pole.

(4) The prismatic groove array or the cylindrical lens array 15 is integrally formed on the outside surface of the propagation direction characteristics modifier 14 used in the embodiments II to IV, V, VI, VIII, IX, XI and XII. However, this structure may be replaced with the following structures, for instance.

The propagation direction characteristics modifier 14 having the flat outside surface used in the embodiment I and the prism sheet having the prismatic groove array or the cylindrical lens array formed only on one surface may be used in separate layers. These elements may be bonded together in use.

(5) The propagation direction characteristics modifier and the reflection pattern sheet in each embodiment may be united with each other by means of bonding or the like in use.

(6) A surface light source device having an additionally increased area of an emitting surface may be formed by connecting a plurality of surface light source devices in each embodiment together so as to form one-dimensional or two-dimensional array.

As has been described in detail in the foregoing, according to the characteristics of the present invention, it is possible to provide a surface light source device of side-light type which includes, in combination, the propagation direction characteristics modifier simultaneously fulfilling the action of deflection to a frontal direction and the action of convergence (an action of improving the degree of parallelization), and the reflection pattern means for controlling light incident on the propagation direction characteristics modifier, and concentratedly radiates a bright illumination flux with a high degree of parallelization to a frontal direction.

What is claimed is:

1. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light supply means disposed along a side end surface of said light guide plate;

23

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

wherein said propagation direction characteristics modifier includes one-dimensional array of a large number of projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface;

at least a part of a side portion of each projection element has a reflective deflection surface having a function of deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes reflection portions formed in a distributed state so as to restrain a flux outputted with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said projection elements.

2. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light guide supply means disposed along a side end surface of said light guide plate;

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

wherein said propagation direction characteristics modifier includes one-dimensional array of a large number of ridge elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface;

said large number of ridge elements are lined up in parallel to said side end surface and respectively have reflective deflection surfaces each disposed at a side portion relatively distant from said light supply means and having a function of deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes a large number of reflection portions distributed in the shape of strips to restrain a flux outputted with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said ridge elements.

3. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light guide supply means disposed along a side end surface of said light guide plate;

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

wherein said propagation direction characteristics modifier includes one-dimensional array of a large number of projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface;

at least a part of a side portion of each projection element has a reflective deflection surface having a function of two-dimensional deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes reflection portions formed in a distributed state to restrain a flux outputted

24

with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said propagation direction characteristics modifier.

4. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light guide supply means disposed along a side end surface of said light guide plate;

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

wherein said propagation direction characteristics modifier includes a two-dimensional array of a large number of pole-shaped projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface;

each of said large number of pole-shaped projection elements has at least one reflective reflection surface having a function of two-dimensional deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes a large number of reflection portions distributed in the shape of grid to restrain a flux outputted with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said propagation direction characteristics modifier.

5. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light guide supply means disposed along a side end surface of said light guide plate;

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

wherein said propagation direction characteristics modifier includes a two-dimensional array of a large number of square-pole-shaped projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface;

each of said large number of square pole-shaped projection elements has three reflective deflection surfaces formed so as to have a function of two-dimensional deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes a large number of reflection portions distributed in the shape of grid so as to restrain a flux outputted with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said propagation direction characteristics modifier.

6. A surface light source device of side-light type, comprising:

a light guide plate with emitting directivity;

a light guide supply means disposed along a side end surface of said light guide plate;

a propagation direction characteristics modifier disposed along an emitting surface of said light guide plate; and a reflection pattern means for controlling light incident on said propagation direction characteristics modifier;

25

wherein said propagation direction characteristics modifier includes a two-dimensional array of a large number of conical-shaped projection elements each having a distal end provided with a flat region serving as an input surface substantially parallel to said emitting surface; 5
 each of said large number of conical-shaped projection elements has a peripheral surface having a function of two-dimensional deflection to a frontal direction based on reflection including the total reflection; and

said reflection pattern means includes a large number of reflection portions distributed in the shape of grid so as to restrain a flux outputted with directivity from the emitting surface of said light guide plate from being incident on portions other than the flat regions of said propagation direction characteristics modifier. 10

7. A surface light source device of side-light type according to any one of claims 1 to 6, wherein said reflection pattern means includes a reflection pattern sheet disposed between the emitting surface of said light guide plate and said propagation direction characteristics modifier, and said reflection portions are formed on said reflection pattern sheet. 15

26

8. A surface light source device of side-light type according to claim 7, wherein said light guide plate has a wedge-shaped cross section having a tendency to reduce thickness according as distance from said side end surface increases.

9. A surface light source device of side-light type according to any one of claims 1 to 6, wherein said reflection pattern means includes a reflection portion formed in a distributed state on the emitting surface of said light guide plate. 20

10. A surface light source device of side-light type according to claim 9, wherein said light guide plate has a wedge-shaped cross section having a tendency to reduce thickness according as distance from said side end surface increases.

11. A surface light source device of side-light type according to any one of claims 1 to 6, wherein said light guide plate has a wedge-shaped cross section having a tendency to reduce thickness according as distance from said side end surface increases. 25

* * * * *

PATENT APPLICATION

**RESPONSE UNDER 37 CFR §1.116
EXPEDITED PROCEDURE
TECHNOLOGY CENTER ART UNIT 2872**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Masahiro GOTO

Group Art Unit: 2872

Application No.: 10/565,242

Examiner: A. LAVARIAS

Filed: January 19, 2006

Docket No.: 126735

For: LIGHT-DIFFUSING SHEET

REQUEST FOR RECONSIDERATION AFTER FINAL REJECTION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In reply to the July 1, 2008 Office Action, reconsideration of the rejection is respectfully requested in light of the following remarks.

Claims 1-8 are pending.

Claims 1-8 are rejected under 35 U.S.C. §103(a) over WO 01/04701 to Moshrefzadeh et al. ("Moshrefzadeh") in view of U.S. Patent No. 6,049,649 to Arai. This rejection is respectfully traversed.

Independent claim 1 recites "a plurality of wedge-shaped parts, each being embedded on the side of the exit surface of the sheet body...[wherein] an end of each of the wedge-shaped parts on the side of the entrance surface is a flat surface parallel to the entrance surface." Applicants respectfully assert that it would not have been obvious, to one of ordinary skill in the art, to try and combine Arai with Moshrefzadeh.

The Office Action asserts that Arai discloses wedge-shaped parts having a flat surface. However, Arai discloses a light modifier sheet for collimating outgoing light. See Fig. 10 and col. 11, lines 30-45 of Arai. By contrast, the purpose of the wedge shapes in both the instant claims and Moshrefzadeh is to diffuse light.

For example, the instant specification explains one of the purposes of the claimed invention is to allow a viewer of an LCD screen to view the image from a wide array of angles. See page 1, lines 8-10 of instant specification. The specification further explains how the recited flat portion, in combination with the recited inclined surfaces of the wedges help diffuses the light in a variety of directions. See Figs. 8-10 of instant specification. Arai, on the other hand, discloses a system for collimating light so that all of the light emanating from the back end of the wedges emerges at a common angle. See Fig. 10 of Arai.

Thus, one of ordinary skill in the art would not have thought the features of Arai, including the flat wedge surface, would aid in the stated purpose of Moshrefzadeh to diffuse light.

Furthermore, the Office Action asserts, as its justification for combination, that it would have been obvious to combine Arai with Moshrefzadeh "for the purpose of allowing light to be transmitted into the wedge-shaped parts without undue light scattering back-reflection." However, this assertion is contrary to the stated expectations of those skilled in the art, as extrapolated from the text of Moshrefzadeh.

At the time the present invention was made, those skilled in the art would not have believed that it was necessary for the light to be transmitted through wedge-shaped parts having a low refractive index. Rather, those skilled in the art would have believed that in order to ensure good light diffusing effect, it would be better to prevent light from entering and transmitting through the wedge-shaped parts. Moshrefzadeh itself supports this conclusion. Moshrefzadeh discloses that a light absorbing material is included in the wedge-

shaped parts. Thus, Moshrefzadeh discloses means for preventing light from being transmitted into the wedge-shaped parts. Thus, one of ordinary skill in the art would not have thought allowing light to be transmitted into the wedge-shaped parts without undue light scattering back-reflection was a useful feature. As such, one of ordinary skill in the art would not have thought it obvious to try and combine the features of Arai with Moshrefzadeh because he would not have believed the combination would succeed.

For at least the above reasons, it would not have been obvious, to one of ordinary skill in the art, to try and combine Arai with Moshrefzadeh. As such, the rejection of claims 1-8 lacks merit. Thus, withdrawal of the rejection of claims 1-8 is respectfully requested.

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 1-8 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,



James A. Oliff
Registration No. 27,075

Moshe K. Wilensky
Registration No. 56,263

JAO:MKW/jfb

Date: September 16, 2008

OLIFF & BERRIDGE, PLC
P.O. Box 320850
Alexandria, Virginia 22320-4850
Telephone: (703) 836-6400

**DEPOSIT ACCOUNT USE
AUTHORIZATION**

Please grant any extension
necessary for entry;
Charge any fee due to our
Deposit Account No. 15-0461

VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA

Eighth Edition

Animal Life
Biosciences
Chemistry
Earth and Atmospheric Sciences
Energy Sources and Power Technology
Mathematics and Information Sciences
Materials and Engineering Sciences
Medicine, Anatomy, and Physiology
Physics
Plant Sciences
Space and Planetary Sciences

DOUGLAS M. CONSIDINE, P.E.
Editor

GLENN D. CONSIDINE
Managing Editor



VAN NOSTRAND REINHOLD

ITP A Division of International Thomson Publishing Inc.

New York • Albany • Bonn • Boston • Detroit • London • Madrid • Melbourne
Mexico City • Paris • San Francisco • Singapore • Tokyo • Toronto



Fig. 1. Change of wavelength and (in general) of direction of wave train upon entering new medium.

It is easy to show that if i is the angle of incidence and r the angle of refraction at such a boundary (Fig. 2), the refraction is governed by a simple relation known as *Snell's law*:

$$\sin i = n \sin r$$

in which n has the same value for various angles of incidence and refraction. This constant n , known as the refractive index, depends upon the character of the wave train and of the two media. Physically it represents the ratio of the velocity of the disturbance in the first medium to that in the second. For light passing from one medium to another in which its velocity is greater, so that $n < 1$, we may, for a sufficiently large angle of incidence, encounter the curious phenomenon known as total reflection.

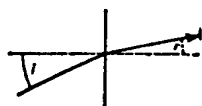


Fig. 2. Angles of incidence (i) and refraction (r).

Refraction often occurs in a single medium due to variations in its properties resulting from changes in conditions through the portion of the medium traversed by the radiation or sound. The twinkling of stars is caused by differences in refractive index in the atmosphere resulting from differences in temperature. Sound also exhibits this temperature refraction.

Specific refraction is a relationship between the refractive index of a medium at any definite wavelength and its density, of the form

$$r = \left(\frac{n^2 - 1}{n^2 + 2} \right) \left(\frac{1}{\rho} \right)$$

in which r is the specific refraction of the medium, n is its index of refraction at any definite wavelength, and ρ is its density. The relation does not always give a constant value of r as the density is varied, and hence must be considered as an approximation.

Molar refraction is the product of the specific refraction by the molecular weight. The form of this relationship is

$$R = Mr$$

in which R is the molar refraction, M is the molecular weight, and r is the specific refraction. The direct form of this relationship is

$$R = \left(\frac{n^2 - 1}{n^2 + 2} \right) \left(\frac{M}{\rho} \right)$$

in which R is the molar refraction, n is the index of refraction for any chosen wavelength, M is the molecular weight, and ρ is the density.

An empirical relationship between molar refraction, density, and molar volume, that applies to many liquids over a considerable range of temperatures is that of Eykman:

$$R = \frac{M(n^2 - 1)}{\rho(n + 0.4)} = \frac{V(n^2 - 1)}{(n + 0.4)}$$

in which R is the molar refraction at a given wavelength, n is the index of refraction at that wavelength, M is the molecular weight, ρ is the density, and V is the molar volume.

Atomic refraction is the product of the specific refraction of an element by its atomic weight.

Standard refraction is the refraction which would occur in an idealized atmosphere in which the refractive index decreases uniformly with height at the rate of 39×10^{-6} per kilometer. Standard refraction may

be included in ground wave calculations by use of an effective earth radius of 8.5×10^6 meters, or $\frac{4}{3}$ the geometrical radius of the earth.

REFRACTION (Astronomical). In any type of astronomical observation, the light from the distant object must pass through the atmosphere of the earth and suffer a change of direction known as refraction. The amount of change of direction depends upon two fundamental factors: the relative refractive index of the atmosphere and the angle that the ray from the distant object makes with the normal to the surface of the atmosphere. Since the normal to the atmosphere is the direction of the astronomical zenith, the amount of refraction will depend upon the altitude of the object, being greatest when the altitude is least, or when the object is on the horizon. The effect of refraction is to make the altitude of an object appear greater than it would be if no atmosphere were present.

To calculate the amount of astronomical refraction, the index of refraction of the atmosphere is needed, and, unfortunately, this quantity varies with meteorological conditions. Various theoretical methods for computing the amount of astronomical refraction have been proposed, but none of them are very satisfactory for altitudes of less than 20° . A fair approximation to the true value may be obtained from the expression

$$R = \frac{983B}{460 + T} \cotan h$$

in which B is the reading of the barometer in inches, T is the temperature of the air in degrees fahrenheit, h is the apparent altitude of the object, and R is the amount of refraction in seconds of arc. More accurate values may be obtained by using refraction tables such as those published in Bowditch American Practical Navigator. These tables give the amount of refraction in terms of observed altitude, and various meteorological conditions such as temperature and barometric pressure. This refraction must be subtracted from any observed altitude. In case changes due to refraction in other spherical coordinates than altitude are desired, the astronomical triangle must be solved.

Sudden and irregular changes in astronomical refraction are produced by varying meteorological conditions, and cause effects of twinkling in the stars.

REFRACTIVE INDEX. The phase velocity of radiation in free space divided by the phase velocity of the same radiation in a specified medium. Because of the Snell law (see *Refraction*) the refractive index may also be defined as the ratio of the sine of the angle of incidence to the sine of the angle of refraction.

The absolute index for all ordinary transparent substances is greater than 1 (see table); but there are some special cases (x-rays and light in metal films, which are discussed below) for which the index of refraction is less than unity. Since the absolute index for air exceeds unity by less than 0.0003, the relative indices for solids and liquids in air are very nearly equal to their absolute indices. It should be noted that since the refractive index varies with the wavelength, any exact statement of its value must specify the wavelength to which it refers; in tables it is usually given for sodium light of frequency 5,893A. See also *Dispersion (Radiation)*.

Substance	Absolute Index
Air	1.0002926
Bromine	1.661
Carbon dioxide	1.00045
Diamond	2.419
Glass	1.5 to 1.9
Glycerine	1.4729
Helium	1.000036
Ice	1.31
Rock salt	1.516
Water (20°C)	1.333

XIV. APPENDIX E - RELATED CASES APPENDIX

NONE